



USB Microscope v3a

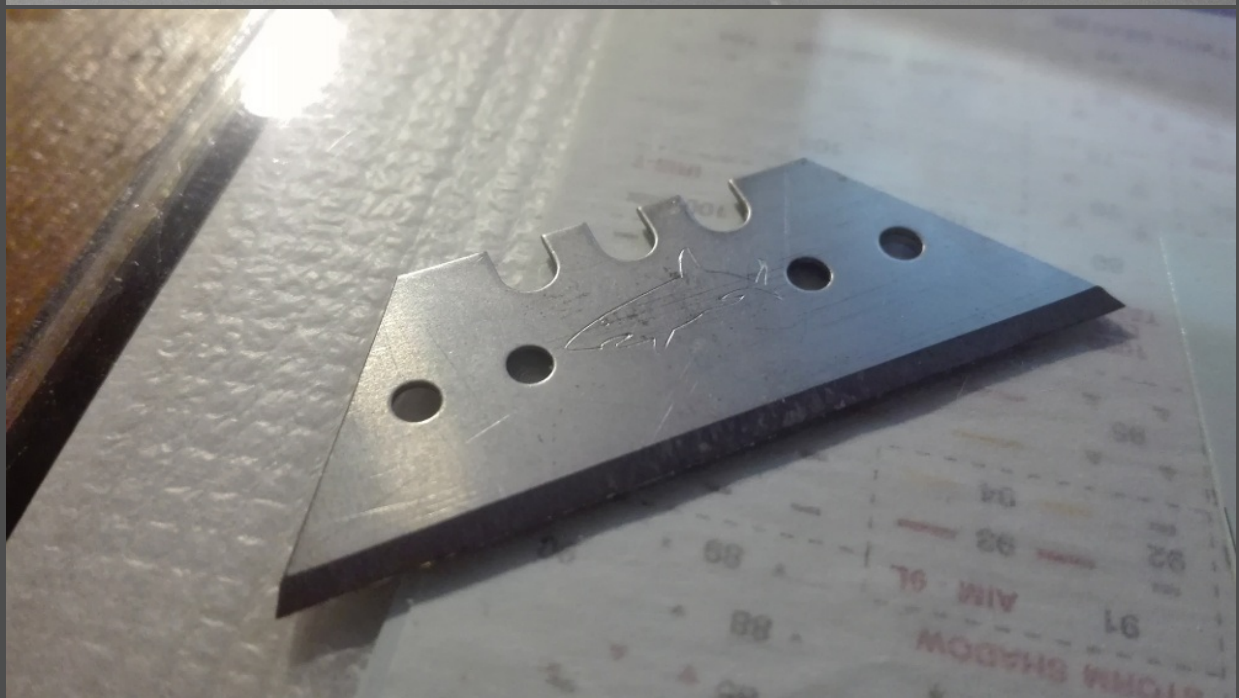
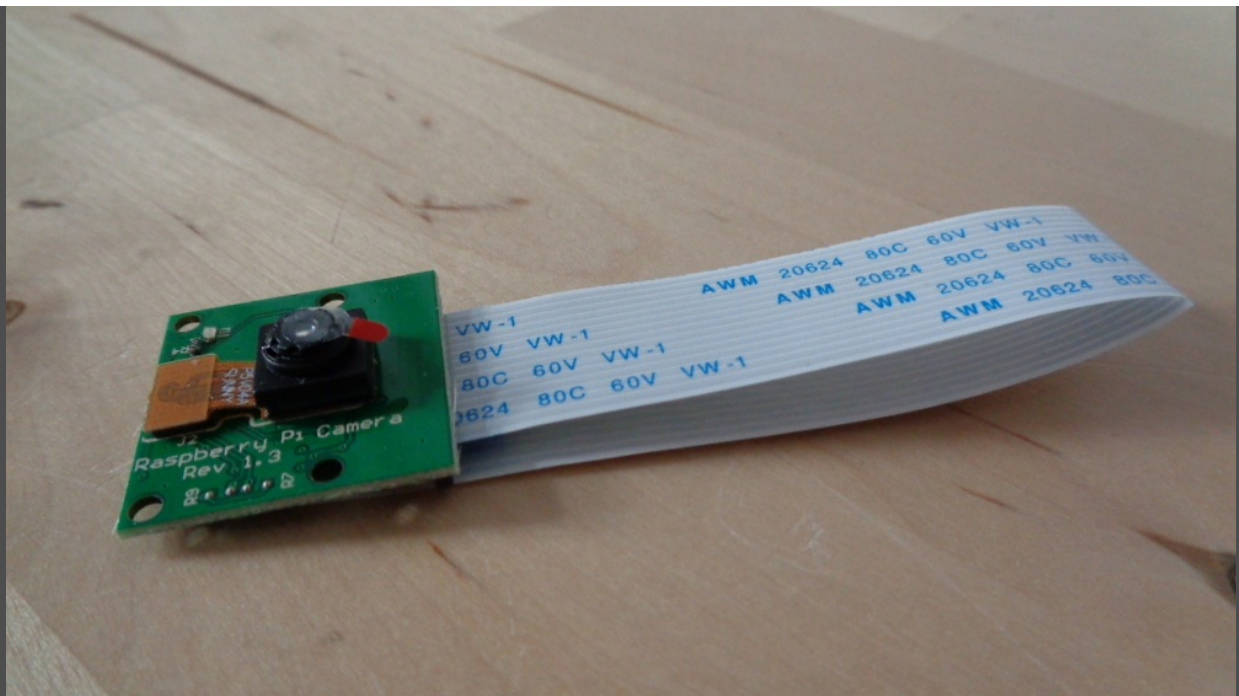
Preface

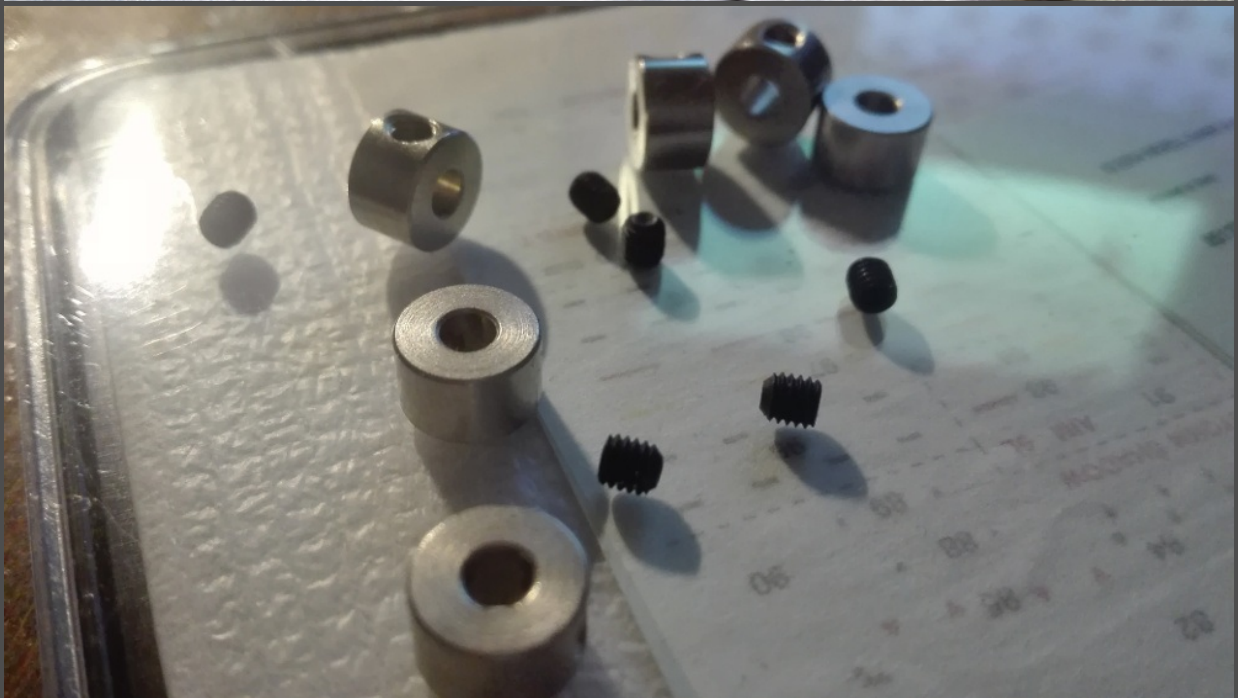
In the last weeks I have invested a lot of time in my [USB microscope](#) project and slowly you can talk about a real prototype. I replaced the old webcam with a [Raspberry Pi Zero](#) and the microscope now has several layers. I also learned a lot from mistakes in this version. I mentioned this in another article sometime, but you really only learn when you make mistakes. Of course I plan all steps theoretically, but you have to work on the experience yourself.

Somehow this is turning into something serious. Actually I just wanted to build a microscope for myself and document the way there, because I do that with all my projects. With this documentation it is a little different, because with every new version I see something that I absolutely want to improve. I also pay attention to cost-effectiveness, i.e. whether the modules/components can be produced cost-effectively. But that would still be a long way to a real release, because the market for USB microscopes is very competitive and there are a lot of (and professional) products.

Materials

In this version some more expensive components were used. I wanted to have the plates for the individual layers created by an online service, but decided against it for several reasons. On the one hand I still had enough material from the white PVC and did not have to produce now extra new garbage, but rather use old material first. The supplier didn't have the right thickness for the plates, which really bothered me. It would also have cost me money, which I would rather invest in a final version, i.e. a professional prototype. This made this version a little *warped*, because I could correct mistakes I had made in the plates only with great difficulty. After this version I wonder if I should use metal instead of plastic. Later it should be produced cheaply and environmentally friendly. Quite a tough task.



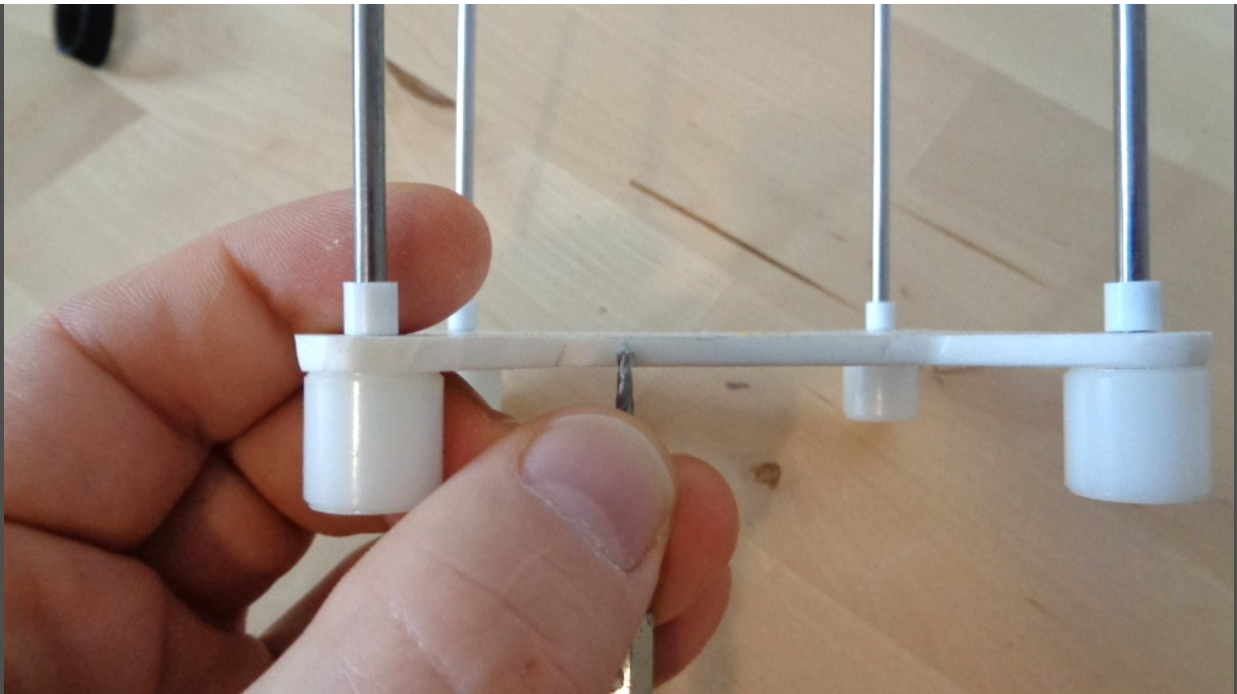




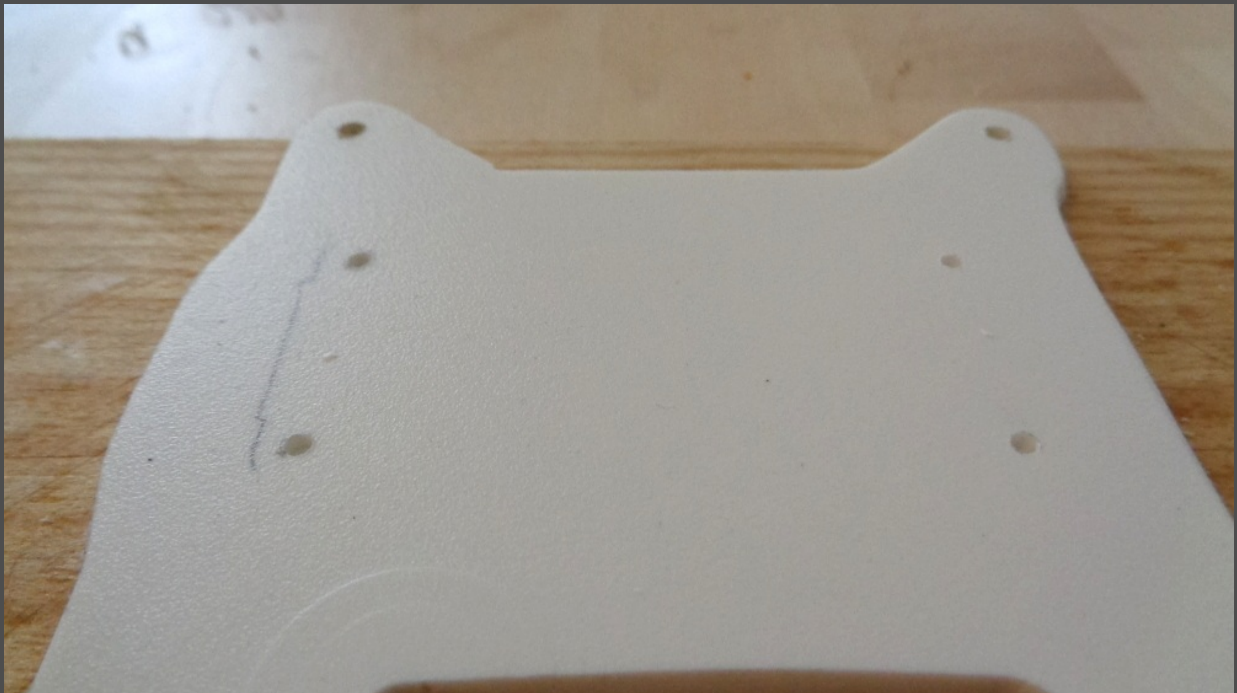
- [USB Microscope V2](#)
- Raspberry Pi Camera Rev 1.3 with Flexcable (blue)
- (orange) Flexcable for Raspberry Pi Zero and Camera (15cm)
- [Precision Knife](#)
- Eight Screws
- Four Lock Screws and Rings
- Four Furniture Glides pads
- Battery Drill with Bits and Drillheads
- Pencil
- Iron-On Beds
- Screwdriver
- Old Paperboard
- Wood Glue and Paintbrush
- Clamps
- Hacksaw
- Eight M2 Bolts
- Four M2 threaded Rod
- Square
- Pliers

Realisation

As I have already mentioned above, I will also point out my mistakes. This will help people to learn more about what they have to pay attention to in their own projects. So you should measure screws *over and over again* on a new project day before you screw them into components. You shouldn't rely on old memories. You can make a mistake quickly, as we can see right away. On the photo you can see how I hold the drill insert next to the plate. With this I try to estimate how far I can drill. To set a mark for me, I taped the rest of the drill with tape. There are also special rings with locking screws, unfortunately I didn't have them in the suitable M1 size.



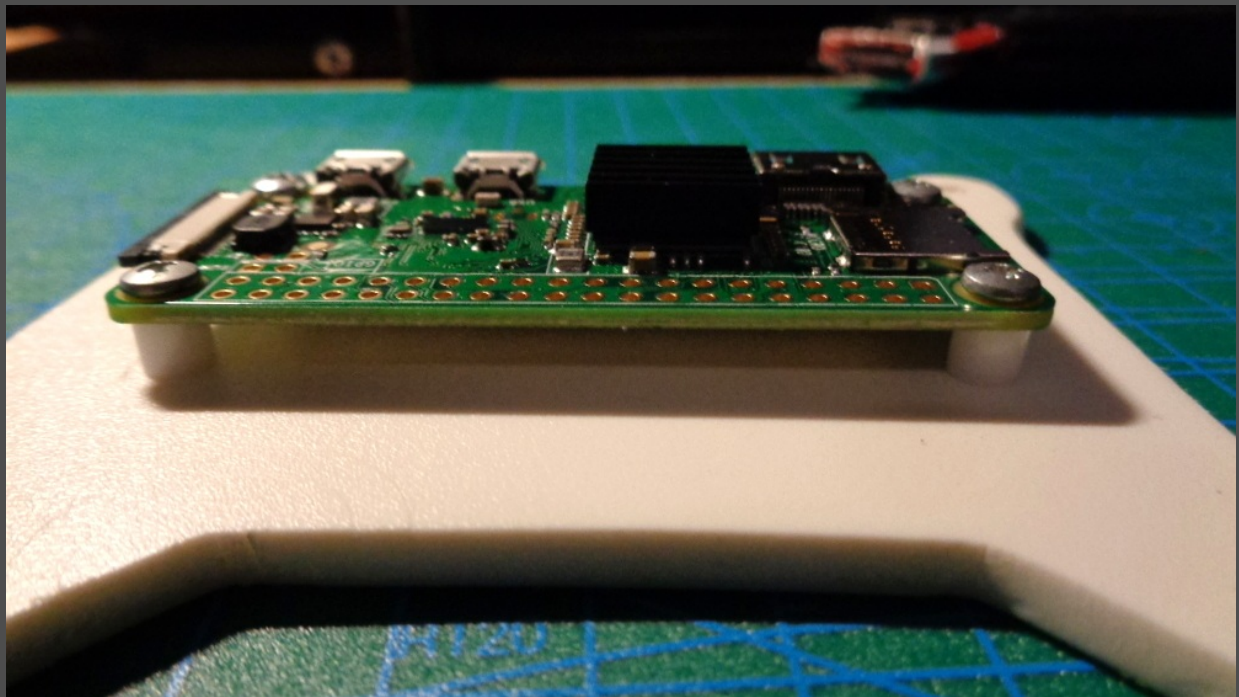
Since I wanted to fix the Raspberry Pi Zero on the plate underneath, I have simply drawn the holes of the board with a pencil on the white plane. As you can see here the connector for the flex cable is on the left side. We recognize this side by the slight slant, which points to the outside. On a car this would be the bonnet. So that I do not get confused with the project I have decided to orient myself to this side. It is on the left side, so that the cables of the Raspberry Pi (HDMI, mains plug, USB) point to the back. The flex cable goes out to the right, to the trunk side. In order to be able to distinguish all levels better, I called the lowest plate *slave layer*. In the further course of the documentation I will only call this layer *slave layer*. On the left it is called *bonnet side* and on the right *trunk side*. With the names you can remember the orientation better and you don't get confused so fast if I count many details at once.



Since I needed eight screws which I didn't want to buy extra now, I looked in my screw box whether I could find suitable there. I also sorted them. At first only by color (black/copper/silver). If I have more time I sort them by brand or function.

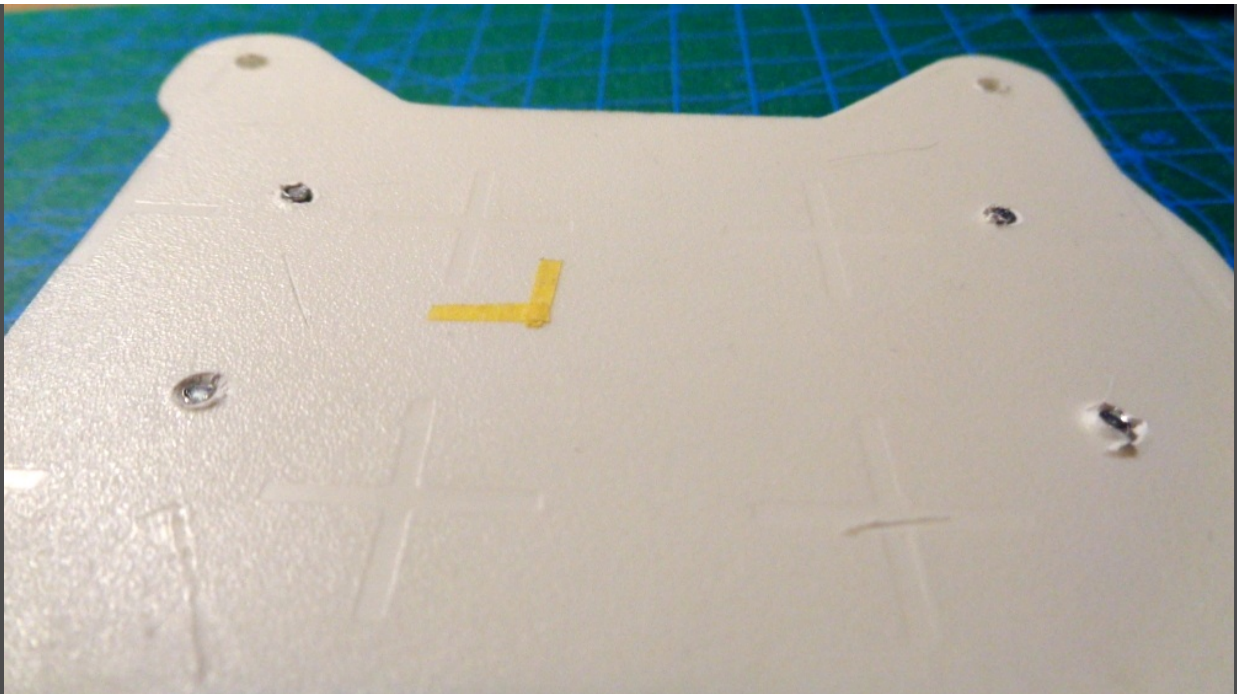


After I found the right screws, I put iron-on beds under the board of the Raspberry Pi Zero again and screwed in the screws. I made my first rookie mistake.

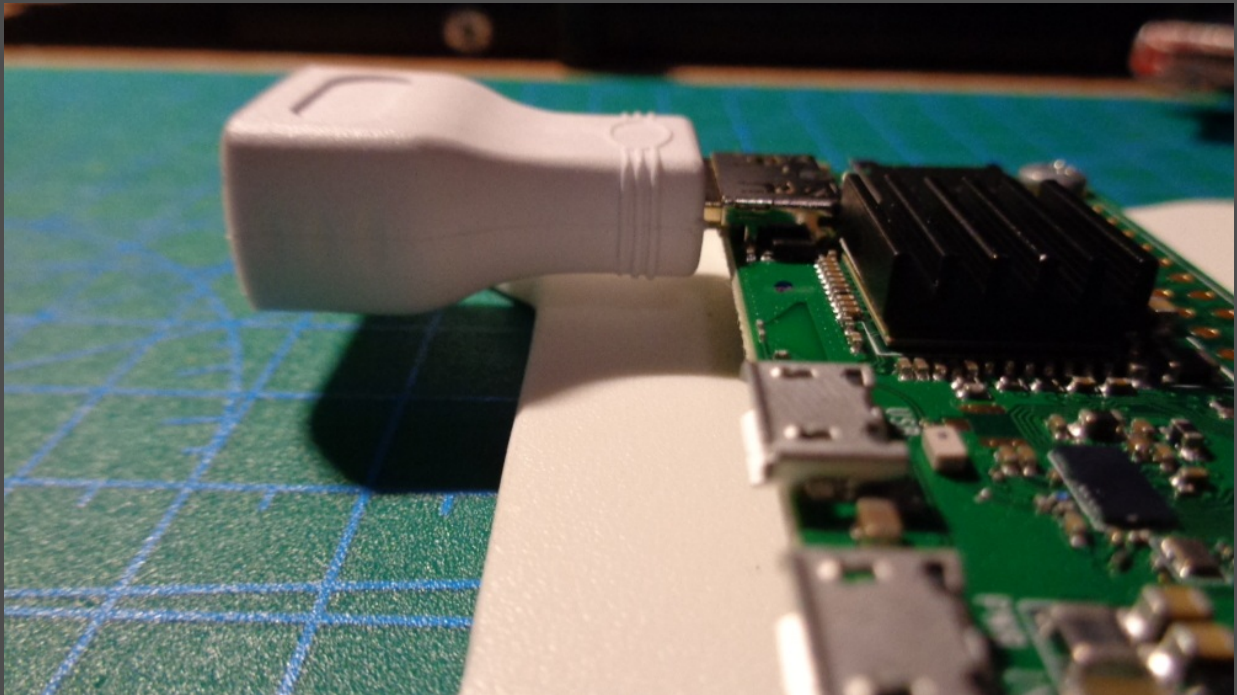


Rookie Mistake I

Unfortunately I was not concentrated for a few minutes and had forgotten to measure the length of the screws before screwing them in. I still had the length of the second version in my head. Anyway I didn't notice how the screws drilled through the plastic on the other side. I had already suspected before that 3mm in the thickness of the slave plane could be too little, but wanted to try it anyway. Even if this meant more work for me now, I find these little insights exciting. This allows you to see how a prototype develops and how errors are corrected bit by bit.



Overall, the idea was already quite good. The external HDMI plug adapts to the shape of the plates, which I liked very much. Also the height was almost perfect to my mental picture.



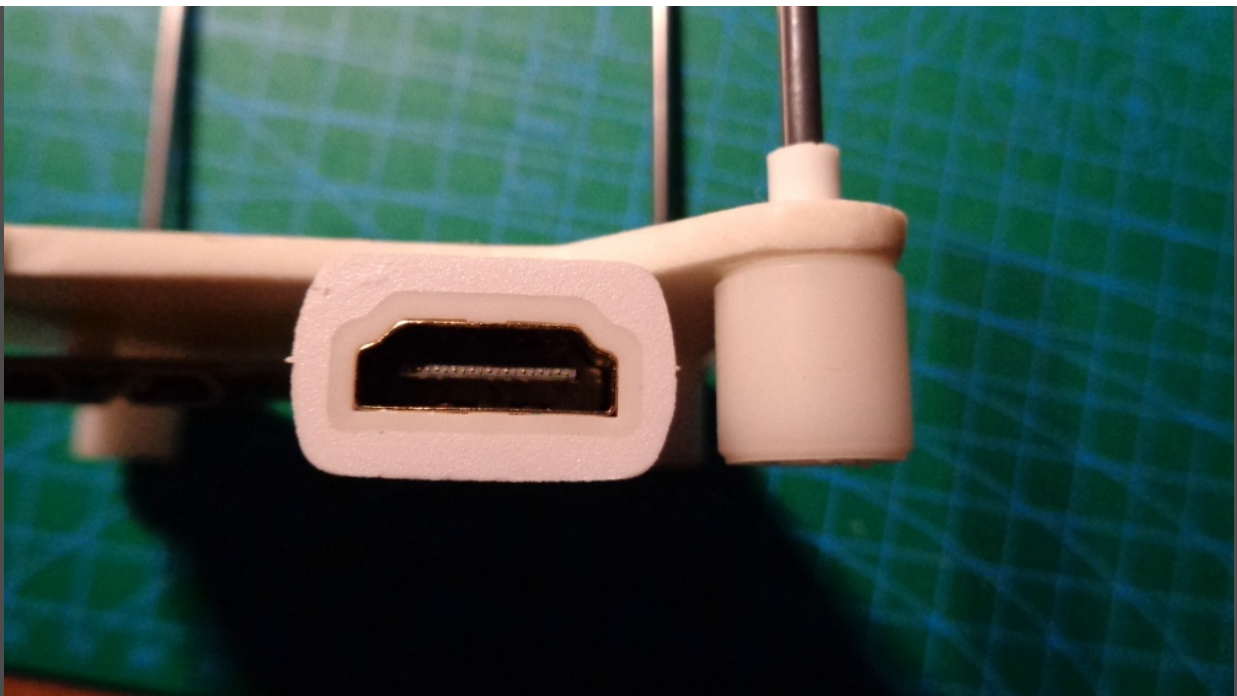
Here you can see on the photo how I tightened the right screw much too tight. This is a problem with my body, which works rather gross motorically. So I could never become a heart surgeon or watchmaker. I try to pay attention to this again and again, but between my brain and my hand signals sometimes simply disappear in nirvana.



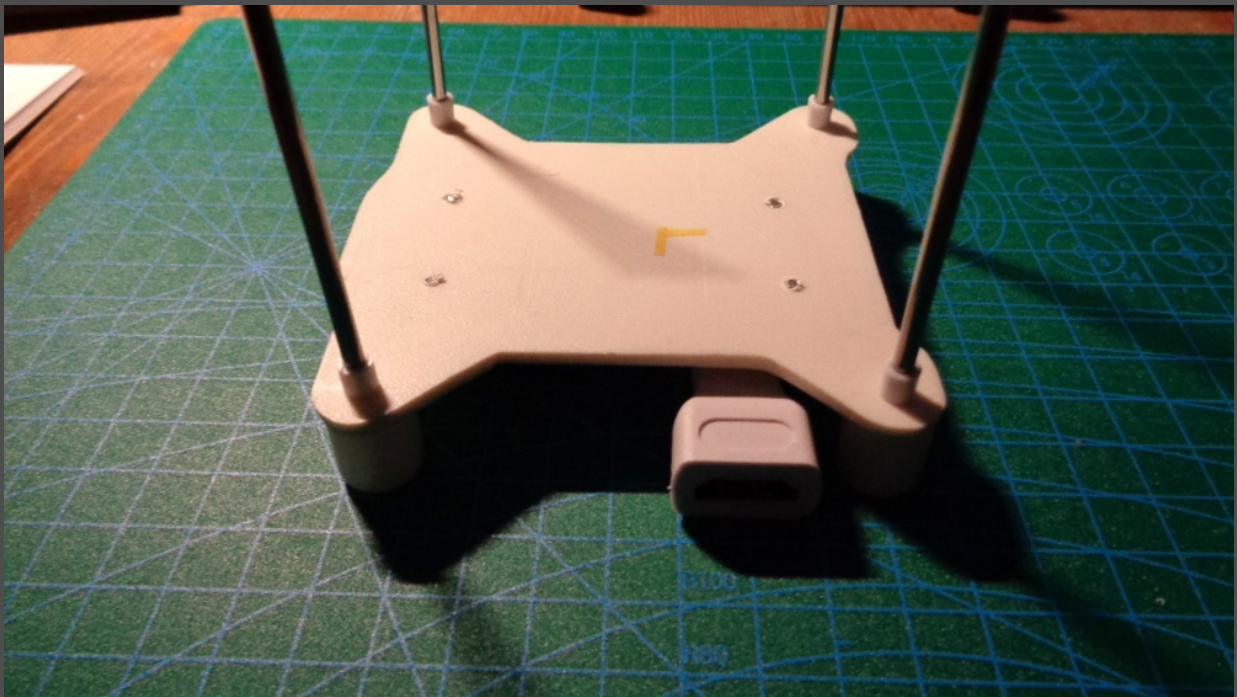
Here you can see how the connector plug for the ribbon cable is still on the bonnet side. At this point I really noticed that I don't like it that way and I have to change the sides.



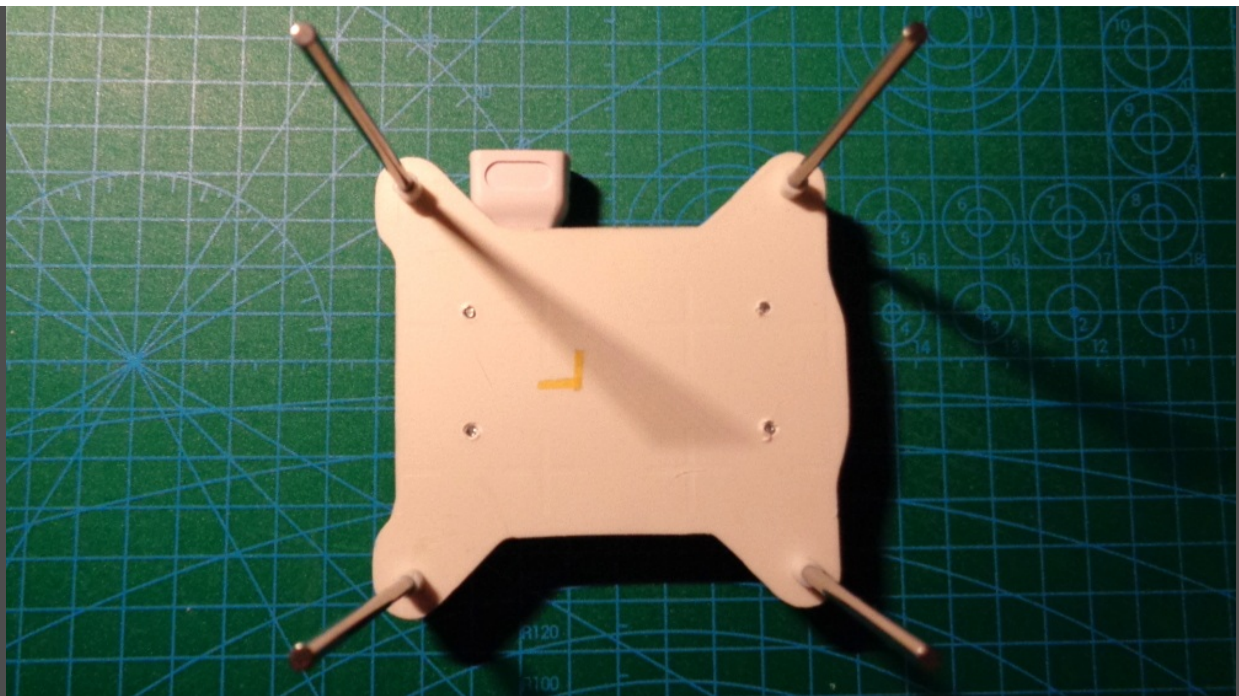
While looking at the page (with the HDMI plug) I noticed another irregularity. The HDMI connector is 2-3mm deeper than the small column on the right side. That doesn't sound like much now, but I always work very hard and it has to fit together very well. If I now place the construction on one layer, the connector bends a little, which in turn causes the component on the board to bend (very little). However, this minimal irregularity is sufficient to additionally load the component and thus promote wear. This allows the connector to break more quickly and nobody wants to buy a new Raspberry Pi Zero all the time just because the builder has slammed the construction.



From a diagonal perspective, everything looks good. That's why it's important to look at your prototypes from all sides and different perspectives so you can also find hidden flaws.

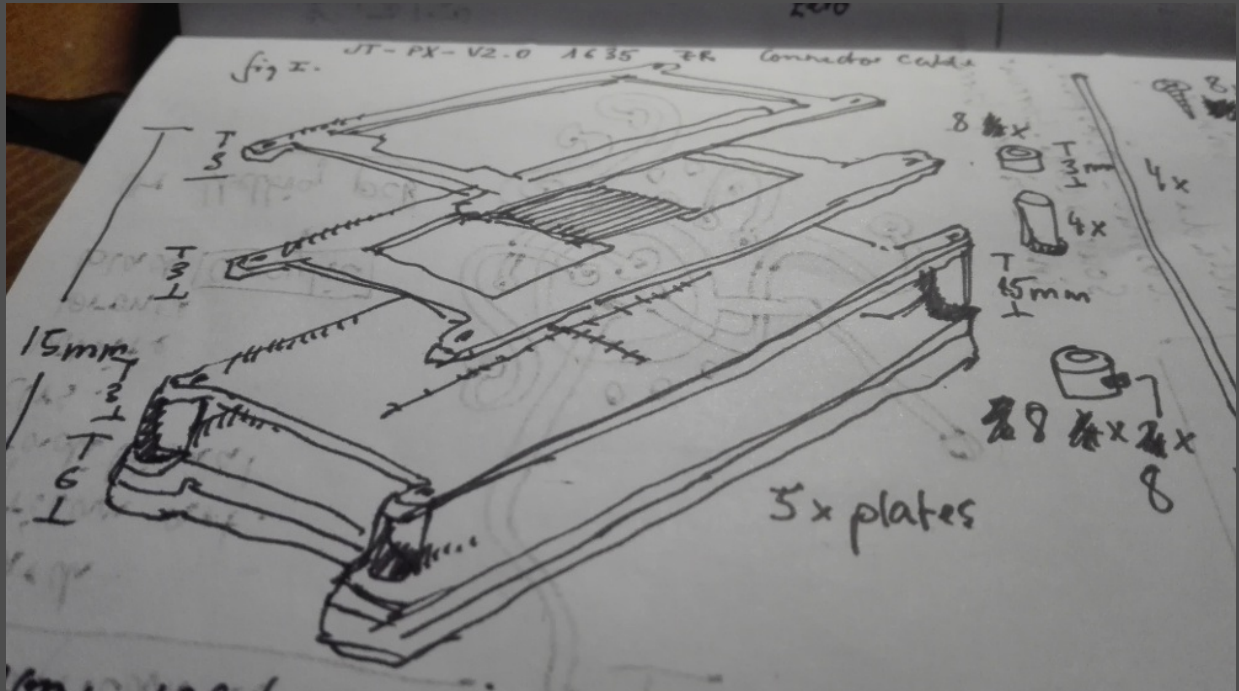


Everything looks good from the top, too. You can still see the iron-on beds on the poles. I left them out later because they are very hard to get off again. Although I want to make everything as safe and durable as possible, it should also be easy to disassemble. The USB microscope is to be divided into individual modules that can be quickly exchanged. It should also be possible to pack the microscope quickly, for example when travelling in inaccessible areas. I am thinking of bio- and archaeologists. Another target group should be students. If you set up the microscope at the beginning of the lesson, don't waste too much time before you can do the first examinations.



Redesign

As we saw in the first chapter, there were some mistakes and problems that I have not seen before. That's quite normal, because you don't develop a perfect prototype the first time. Most inventors like [Alexander Graham Bell](#), [Nikola Tesla](#) or Guglielmo Marconi needed several attempts to develop working prototypes. They had to deal with difficult technical questions and many of these inventors unfortunately failed until someone else rediscovered their ideas and developed them to maturity. To save me time and unnecessary work, I made many drawings and went through the construction in my head. This sometimes allows me to sort out some stupid ideas beforehand. It is helpful to draw the construction from all perspectives. And yes, I saw the mistake in the drawing but ignored it before I took a picture because I didn't have a suitable pen within reach.



Since the slave level should become 6mm thick, so that I can attach the Raspberry Pi Zero better, since I did not have material in this thickness available, I had to improvise there a little bit. I cut out two 3mm pieces in the right size.



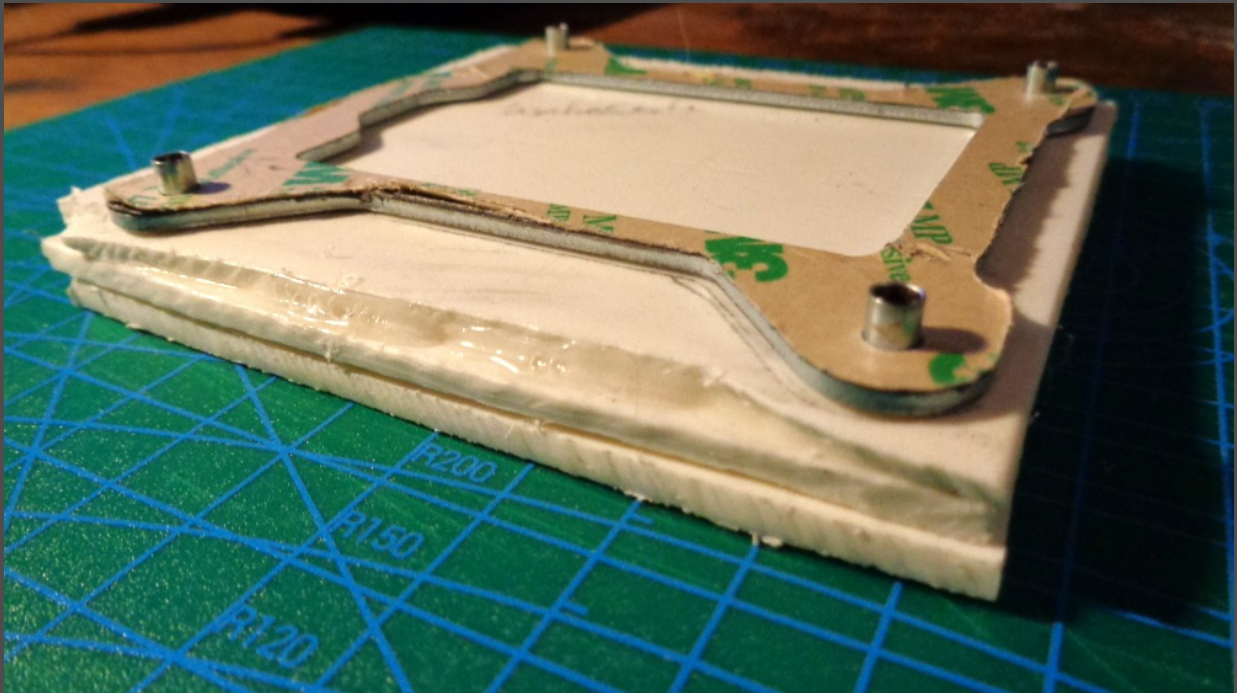
In order to join these two panels together, I decided to use wood glue. I have enough of this in stock and it doesn't matter if I use a little more glue than necessary. Of course you can also use other adhesives, unfortunately I haven't tested it and can't tell you how the material reacts. There are e.g. strong industrial adhesives that can soften plastics. This happened to me as a very small child with my Lego bricks, because I wanted to stick a house together permanently. So you have to test for yourself what works well. Wood glue is ok, but not perfect. I remember reading somewhere that the two surfaces stick better if you sand them with a piece of sandpaper before, but I have no idea where or if it's just a fake memory.



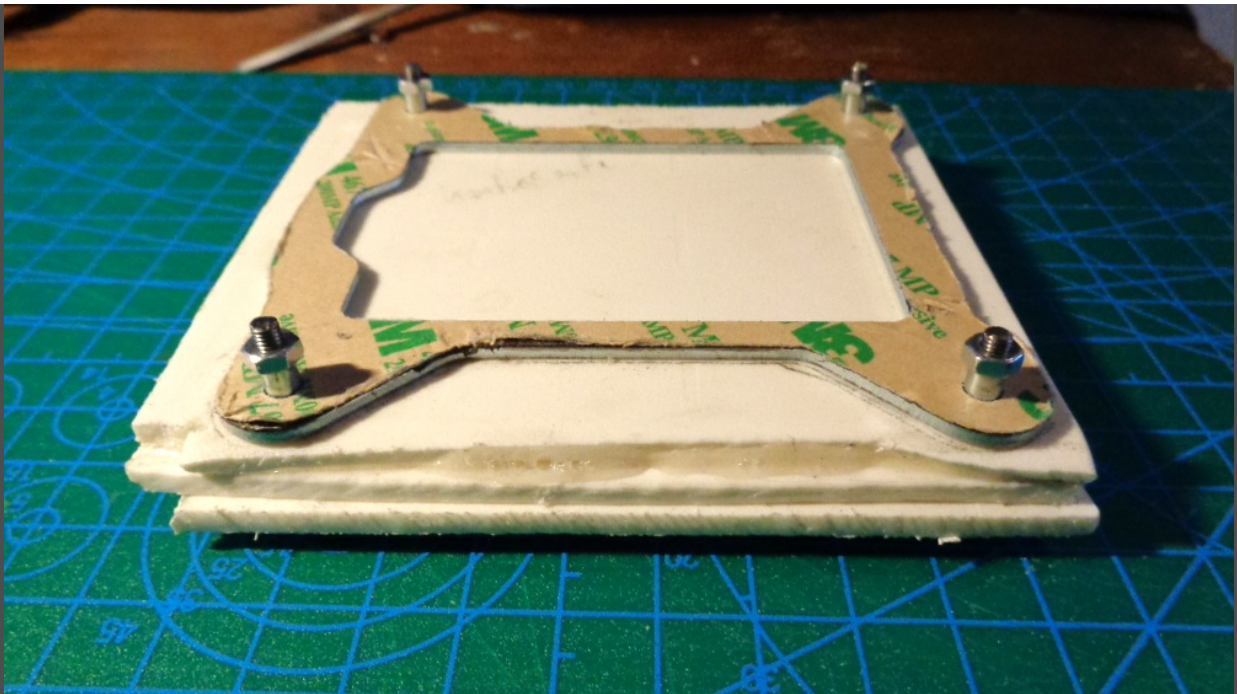
After I coated both plates with sufficient wood glue, these were fixed with clamps. Since I wanted to make sure that everything was glued well, I put the material on the windowsill for 24 hours. I put the heater up so that everything dries out faster.



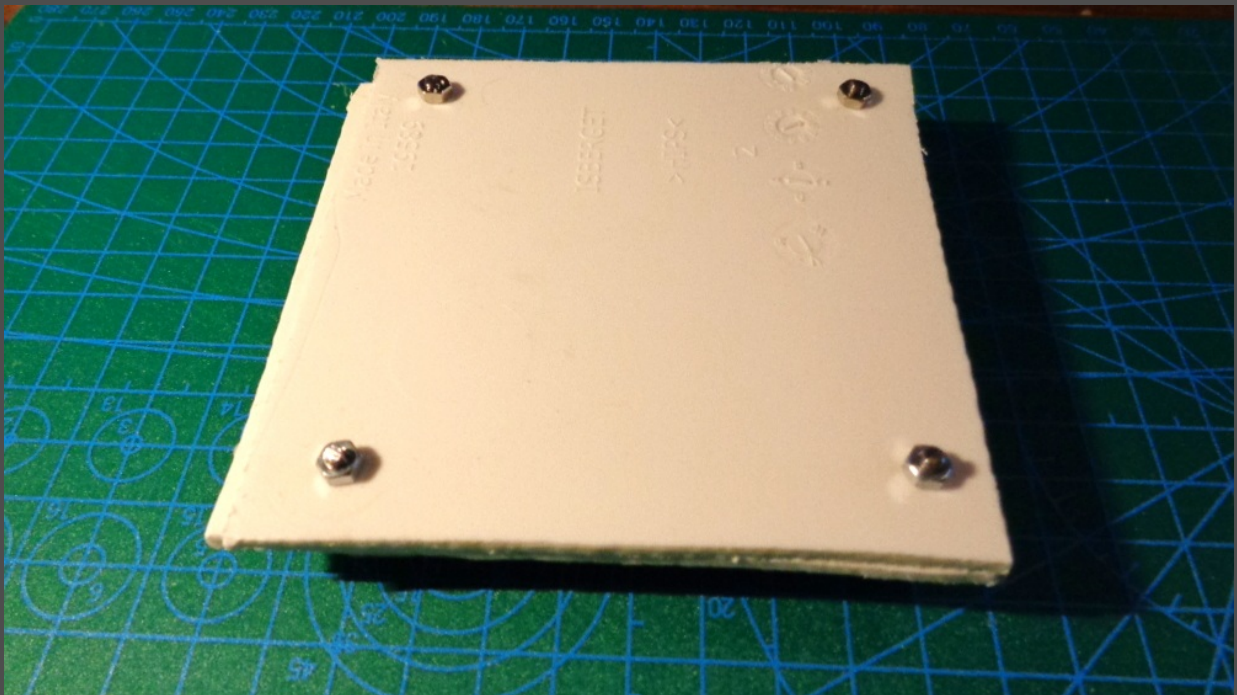
A technical process that I developed in the second version is the joining of the master and slave level. With this I can saw, carve or grind without removing too much material. Since the master is made of metal, I don't have to worry about accidentally making a mistake.



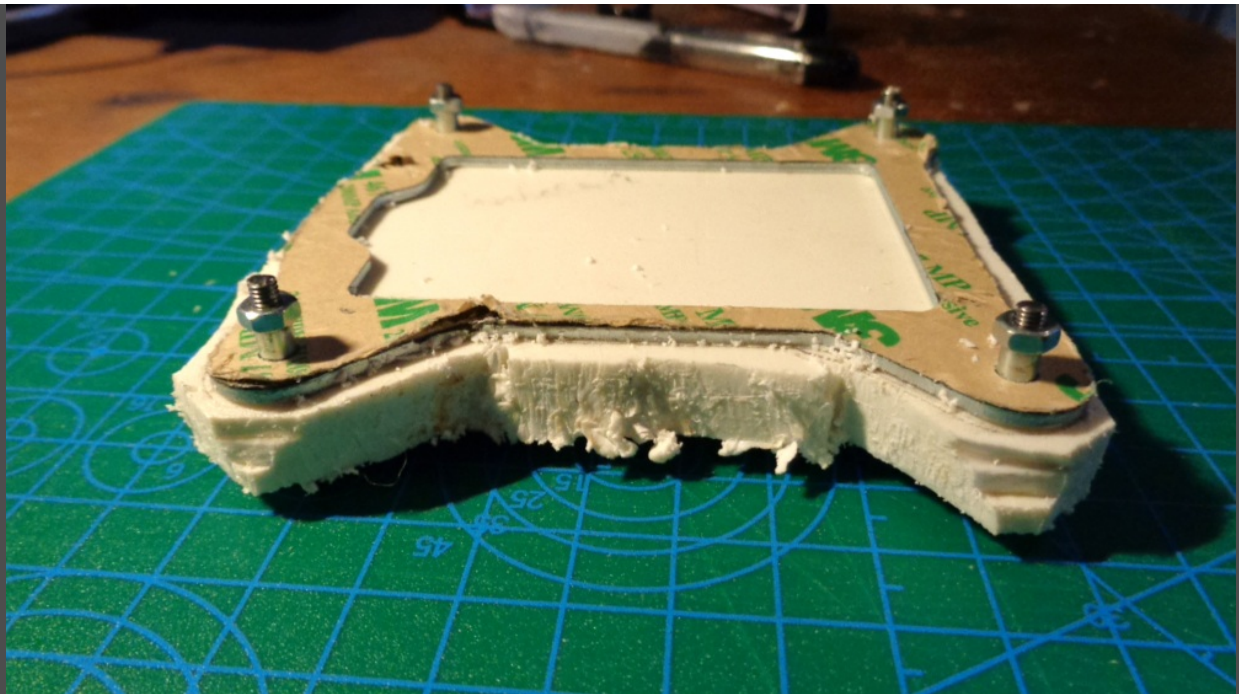
Since this time I had to use thicker material (6mm (slave level) + 3mm (master level) = total 9mm), I bought extra new nuts and a M2 (2mm) threaded rod (1m) and sawed with a hacksaw into suitable pieces. The material was not expensive now, but I could be sure that everything fits exactly.



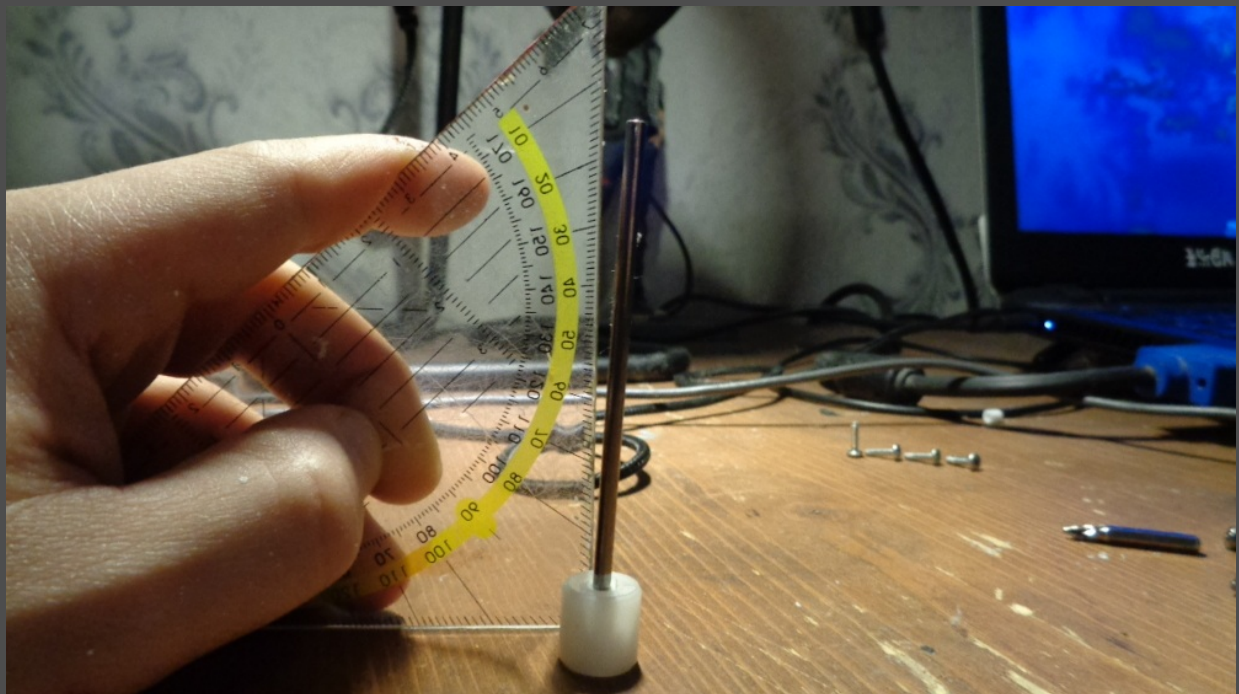
This is the underside with the screws. As you can see at the ends of the threaded rods, I only sawed them out very roughly. Nothing has to be perfect, just hold and press the plates together.



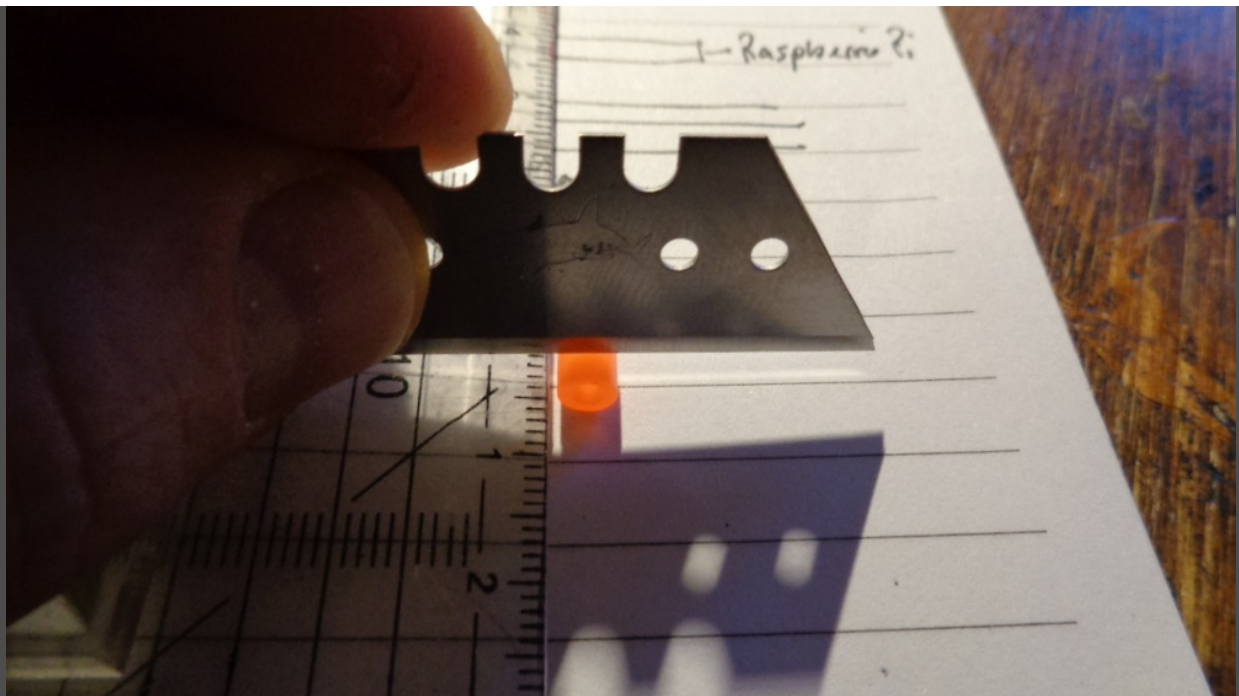
In the [second version of the USB microscope](#) I already described in detail how I worked while sawing out. Therefore there is only one single photo of an intermediate step without documenting the whole process.



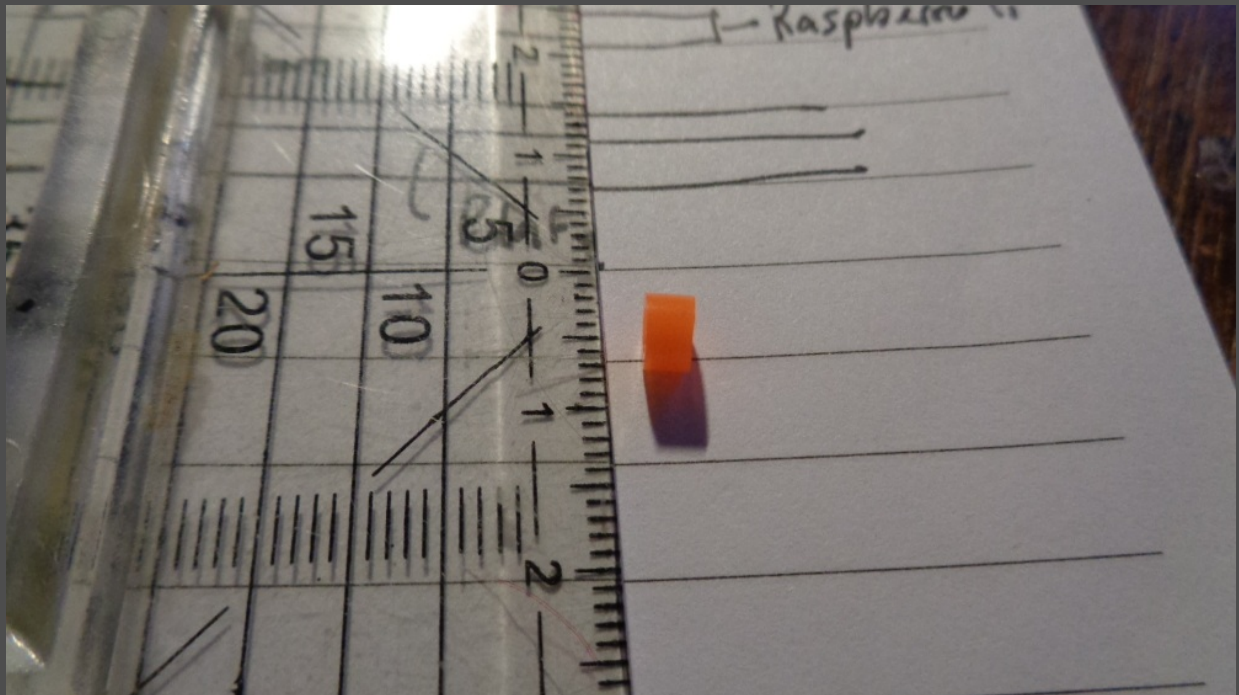
In between I noticed that after a few days a bar has massively distorted. The idea with the iron-on bobs within the small roles was apparently not so good and I will look for another solution in the next versions. The rolls weren't completely filled, which I found practical because it reduces the weight of the whole construction. Sometimes these are also points you have to consider. How much weight does a component have and can you reduce the total weight without compromising stability? This question is extremely important when the [project is scaled](#). Nobody is interested in the weight of four small rolls (you should be interested), because what happens when production is increased to 5,000,000,000 units. 5 million parts weigh a little more and that affects transport costs. In addition one should pay attention to the fact that components are always produced Bi (2). [2, 4, 6, 8](#) is better to produce than 1, 3, 5 and 7. I will explain this in more detail in future versions. Just imagine that your prototype has to be transported to the International Space Station (ISS) with a [Space-X](#) rocket and you have to pay 1000€ for every single milligram. These aren't realistic numbers now, of course, but large numbers will help you better understand where to save to produce an economical portable prototype.



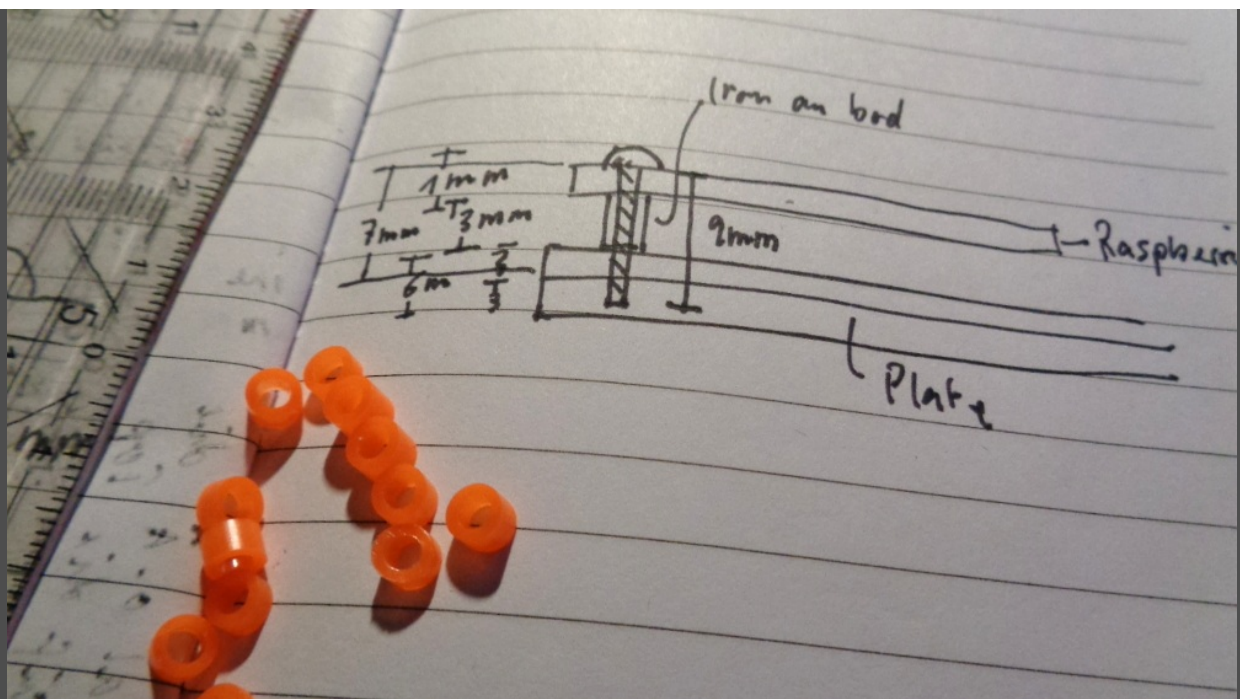
Since the height of the iron-on beds is generally too high, I had to cut them to a suitable length. Here I do it without my [iron-on bed cutter](#), so it's not so clean yet. I also practiced with orange parts to find a suitable technique.



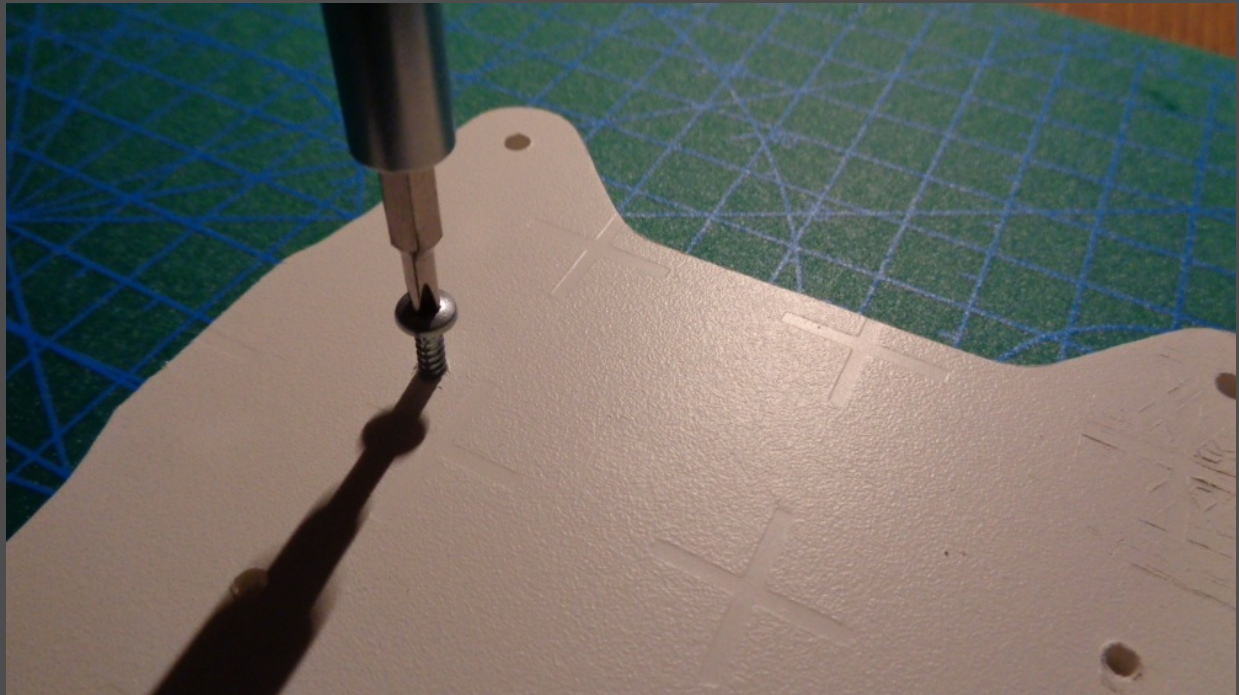
To measure the suitable length I used a simple triangle which is also used in math lessons in school.



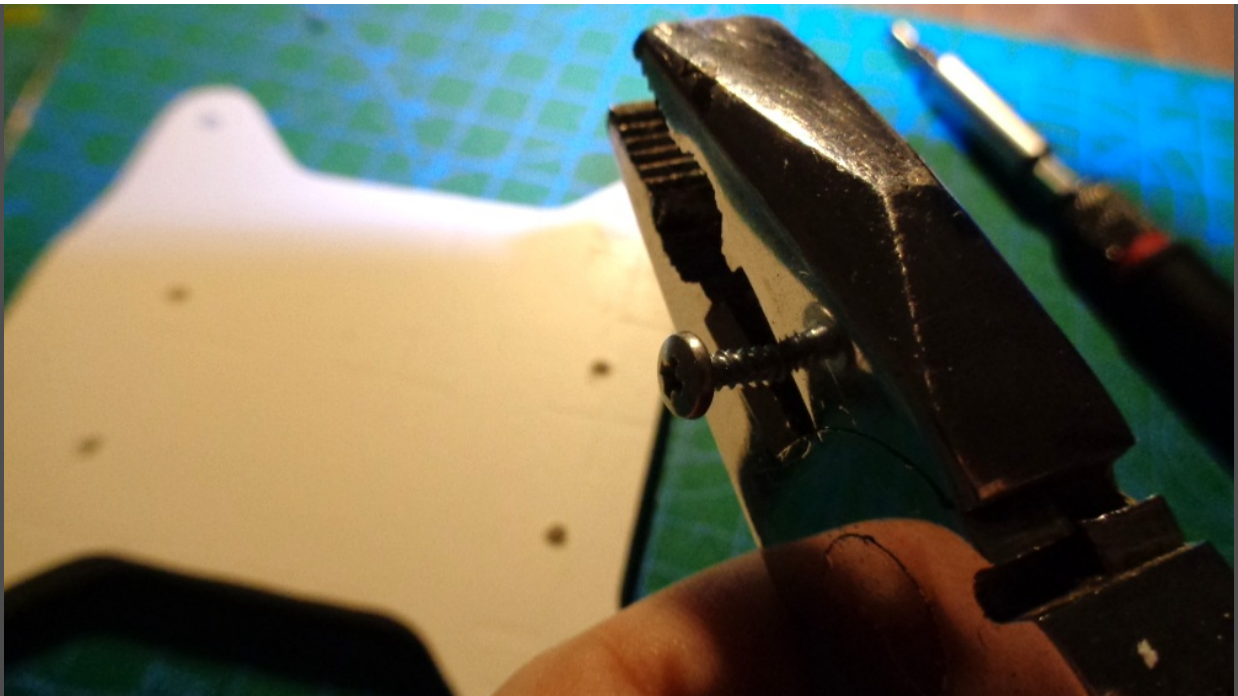
Here you can see the drawing for the construction of the Raspberry Pi Zero. In order to be able to work and plan more exactly, I have dimensioned all thicknesses of the plates etc.. As you can see the total height is 9mm and only for the slave layer. So you can imagine how fast you can reach a really big height, if you don't reduce a few mm in between.



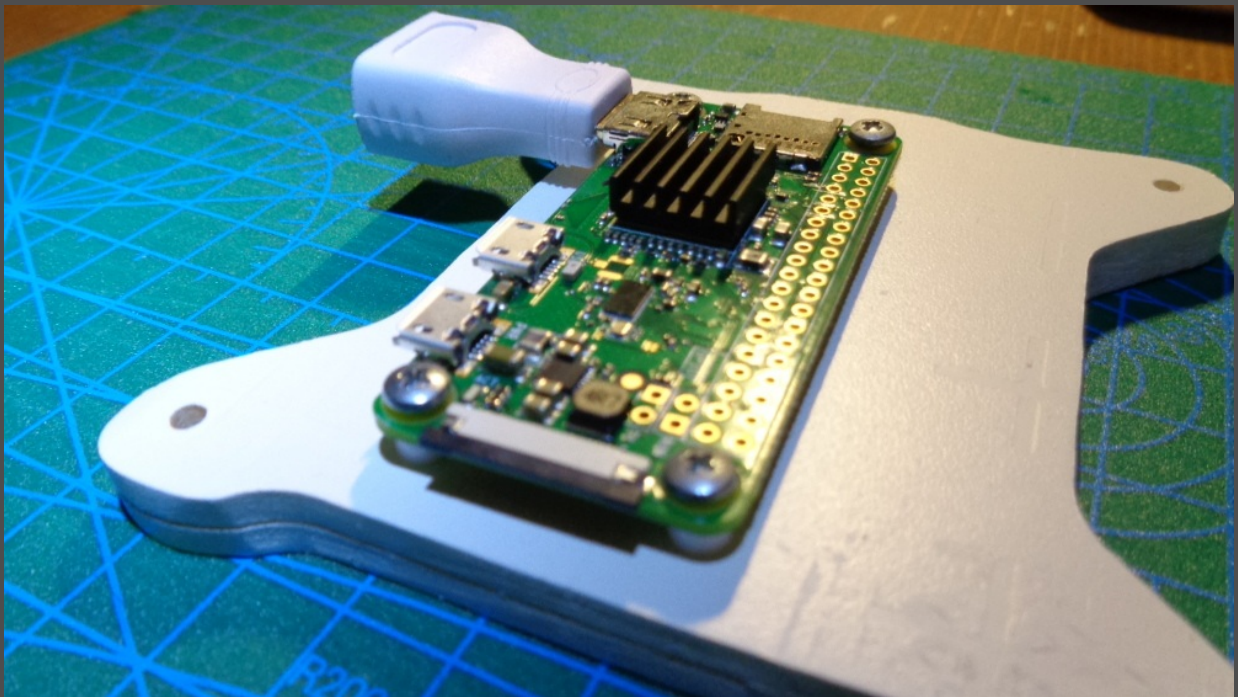
Since I don't have a wind cutter for sizes above M4 yet, I had to prepare the drill holes with the screws. I simply screwed them in and out with a screwdriver. This creates a simple thread in the drill hole and the screw can grip better when screwing in.

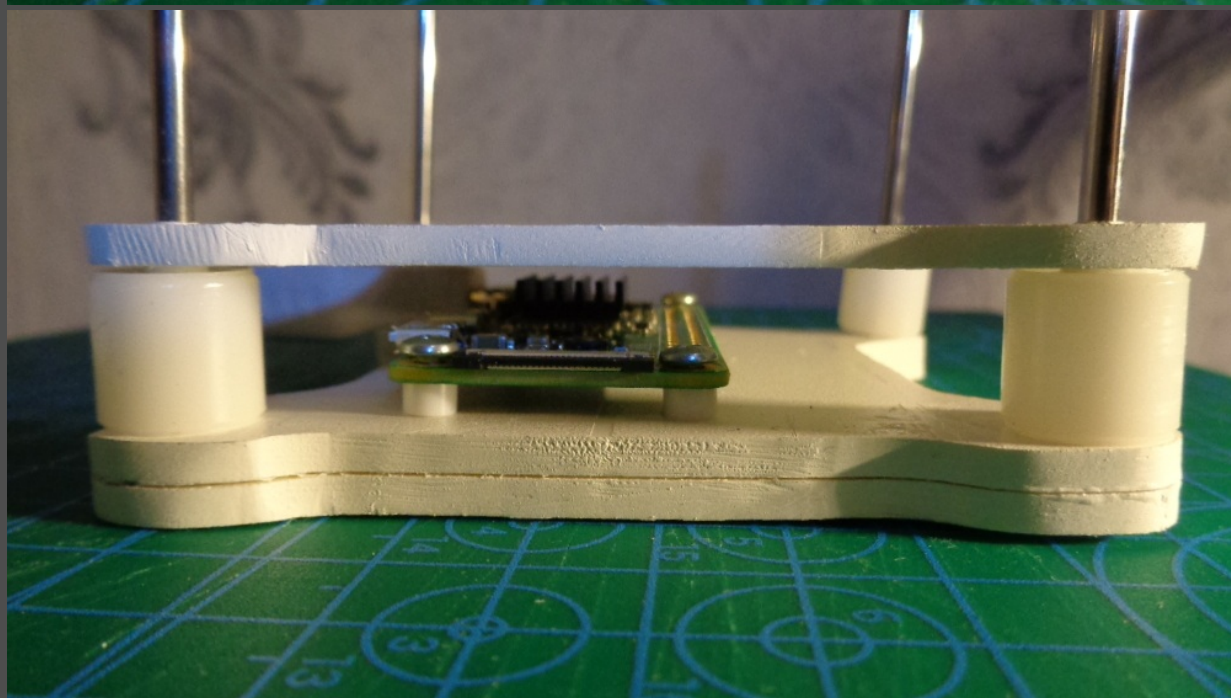
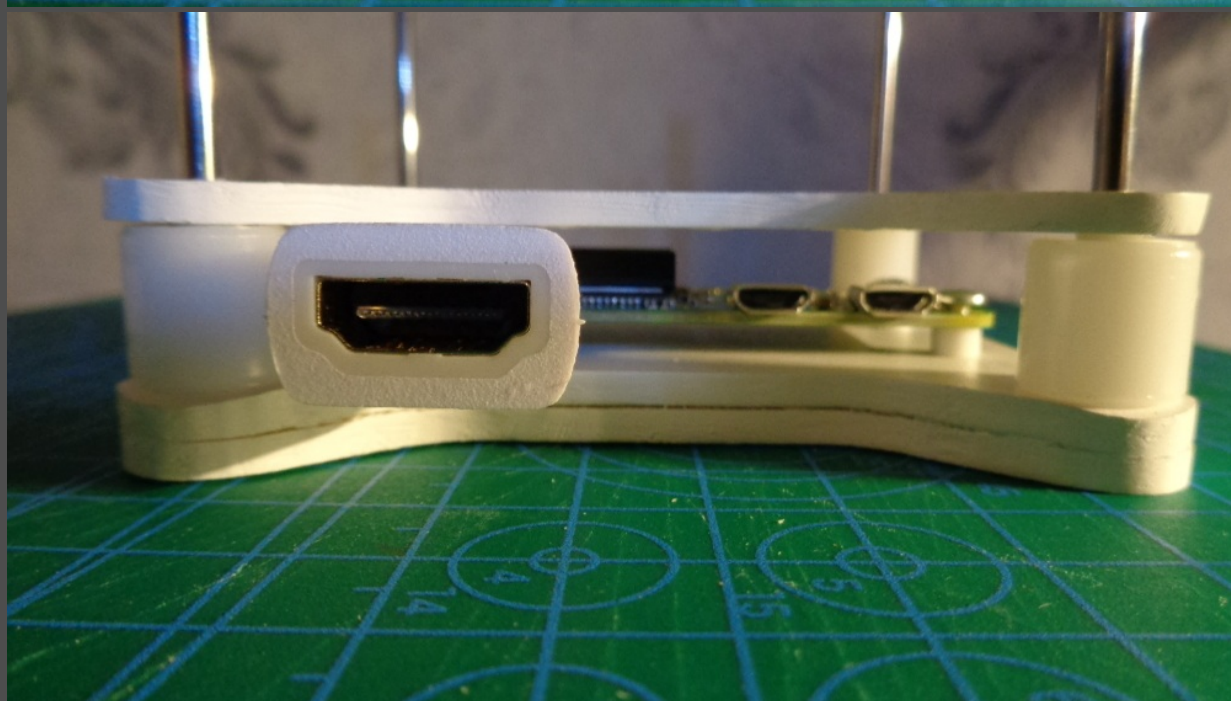
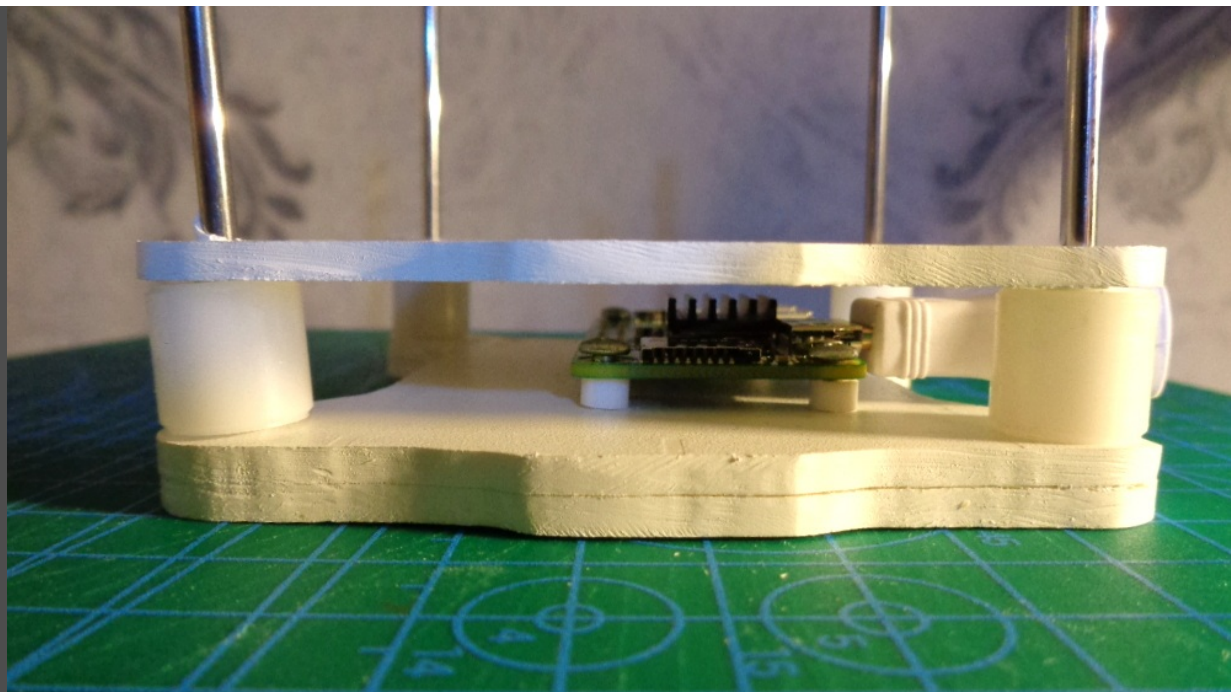


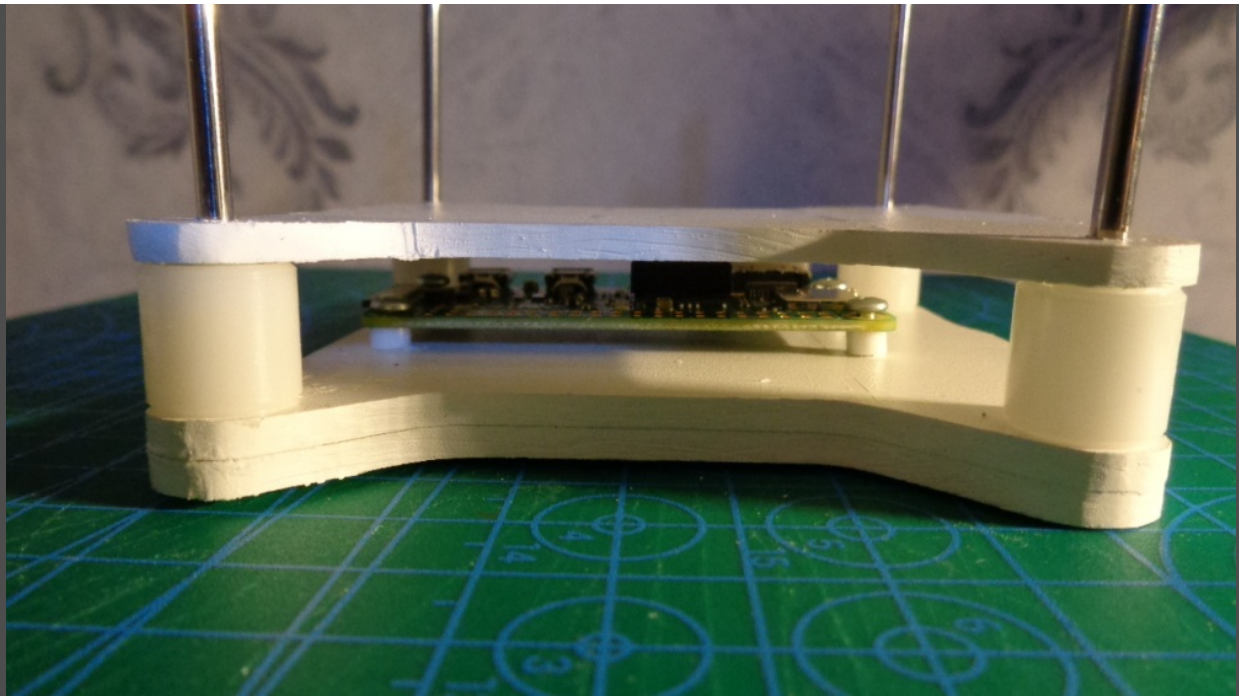
Since I had shortened the iron-on beds and I wanted to avoid turning the screws through the slave plane this time, I shortened them with a pair of pliers. That was about 2mm. If you have screws of a suitable length, you can do without this intermediate step.



After we have screwed on the Raspberry Pi Zero we can put on the *objekt layer* and are finished with the first part of the third version of our microscope.

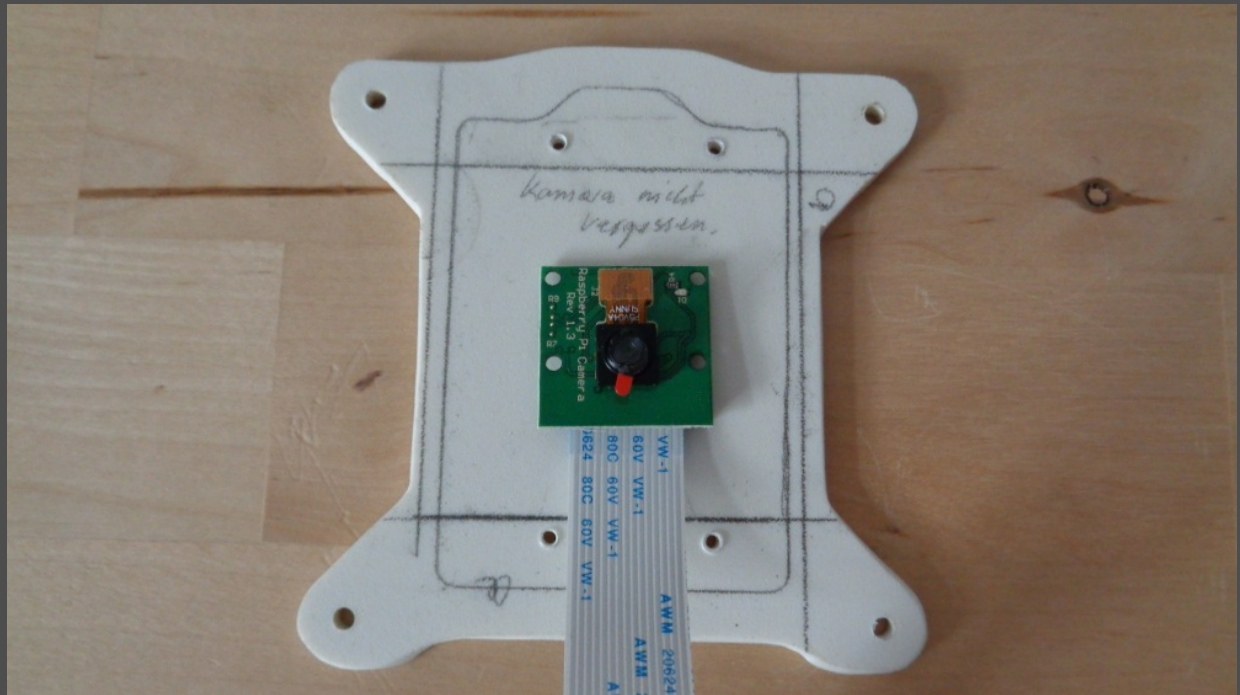




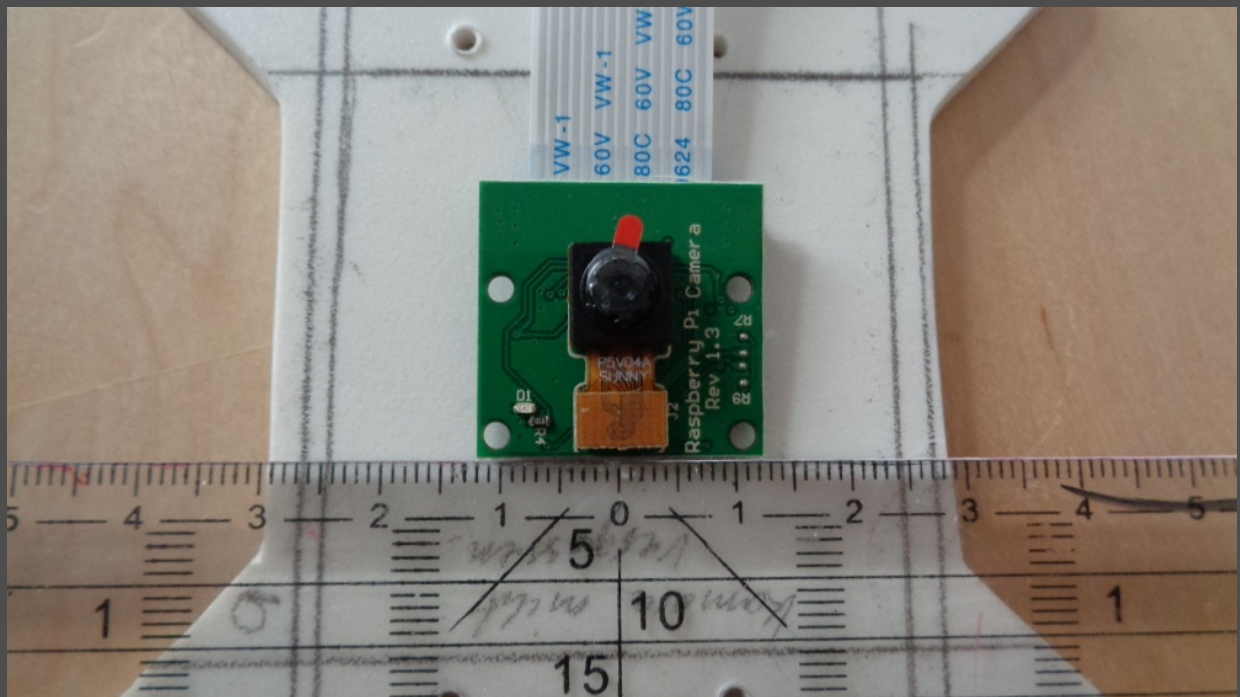


The Camera Layer

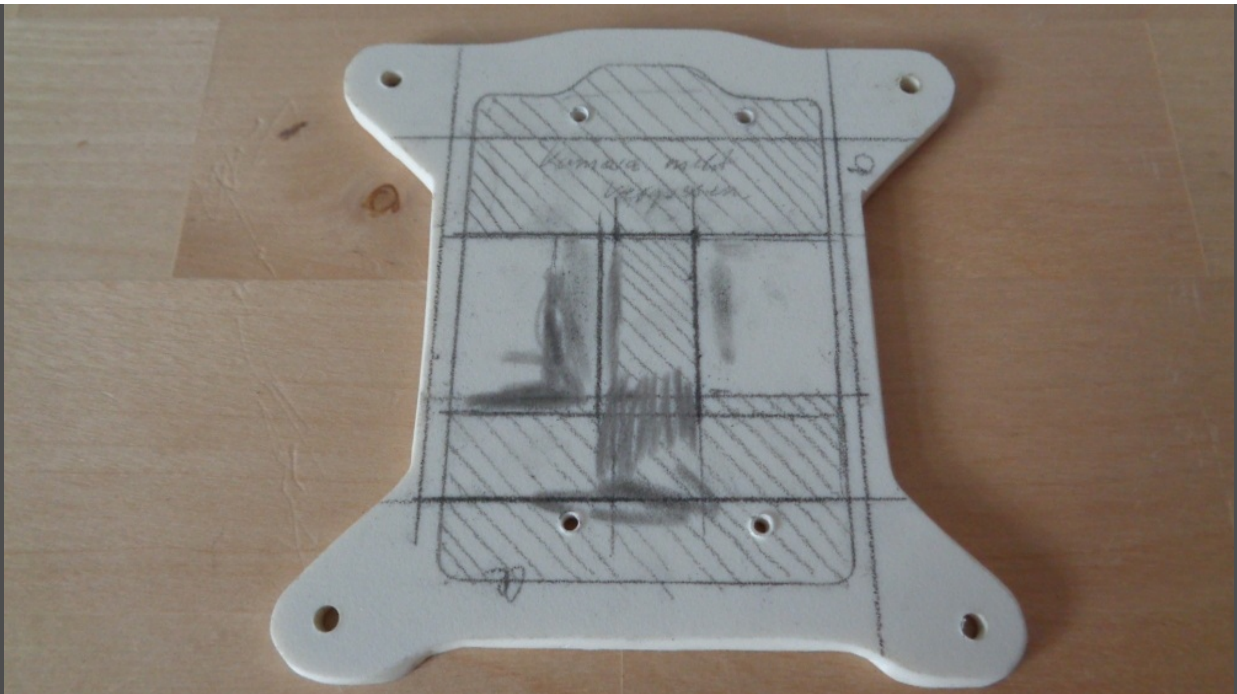
In the second part we edit the camera layer. It should be adapted to the other shapes, but in the middle it should carry the camera. In the first version I didn't come up with a specific style for the two mounts, but simply implemented it. First I have to test if the idea works at all, because the functionality comes before the design.



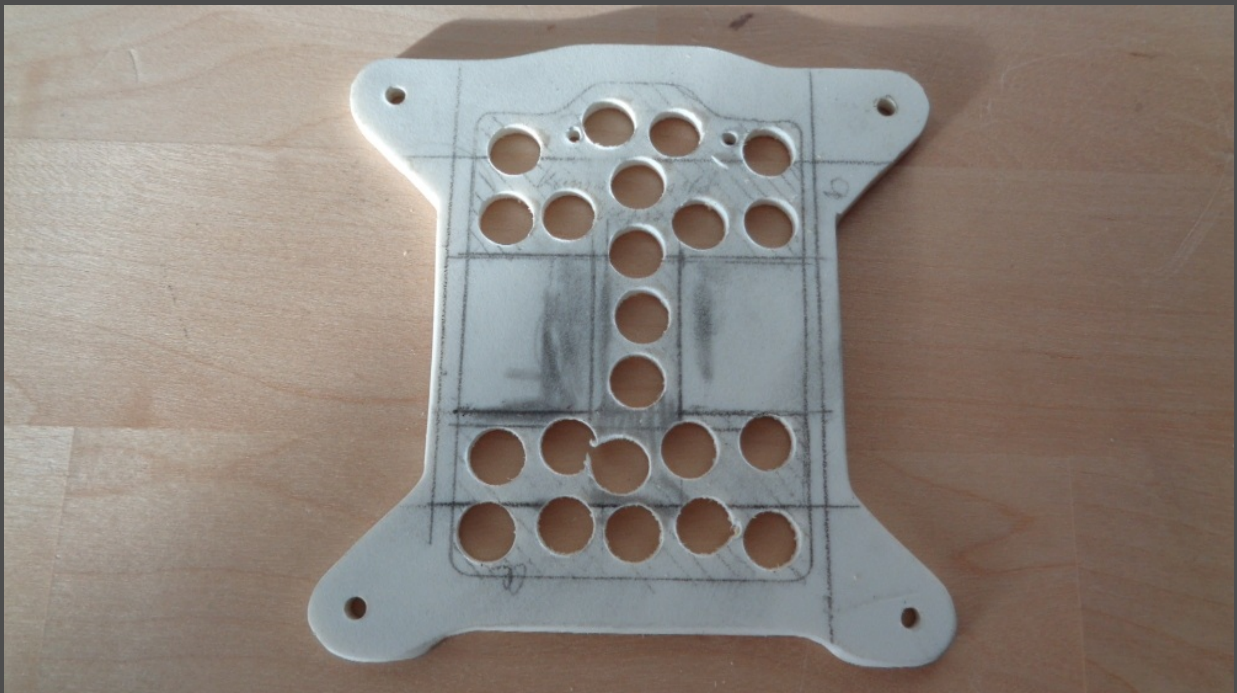
In order to be able to position the board of the camera exactly, we measure the center. The total width of the board is 2.4 mm. Thus, there is a dimension of 1.2 mm on each side.



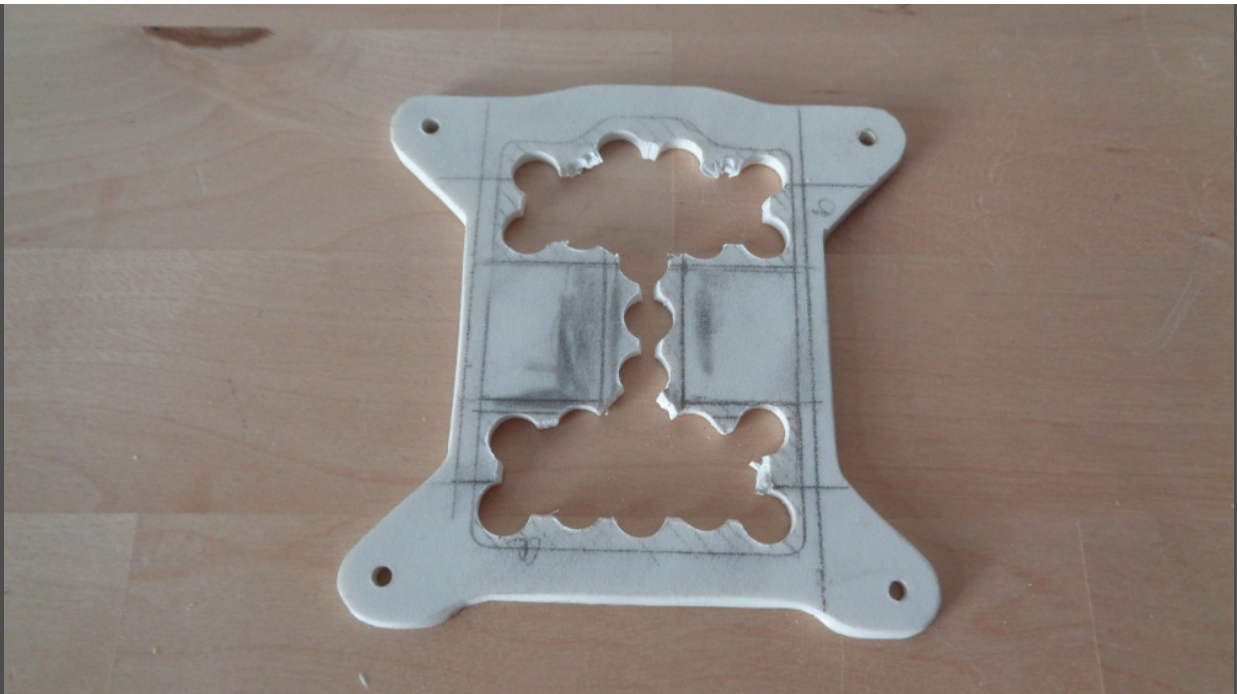
I drew the dimensions with a pencil. The areas with the diagonal lines are sawn out. As you can see, I've listed myself a few times, but that's ok. That's why we'd rather use a pencil than a permanent marker.



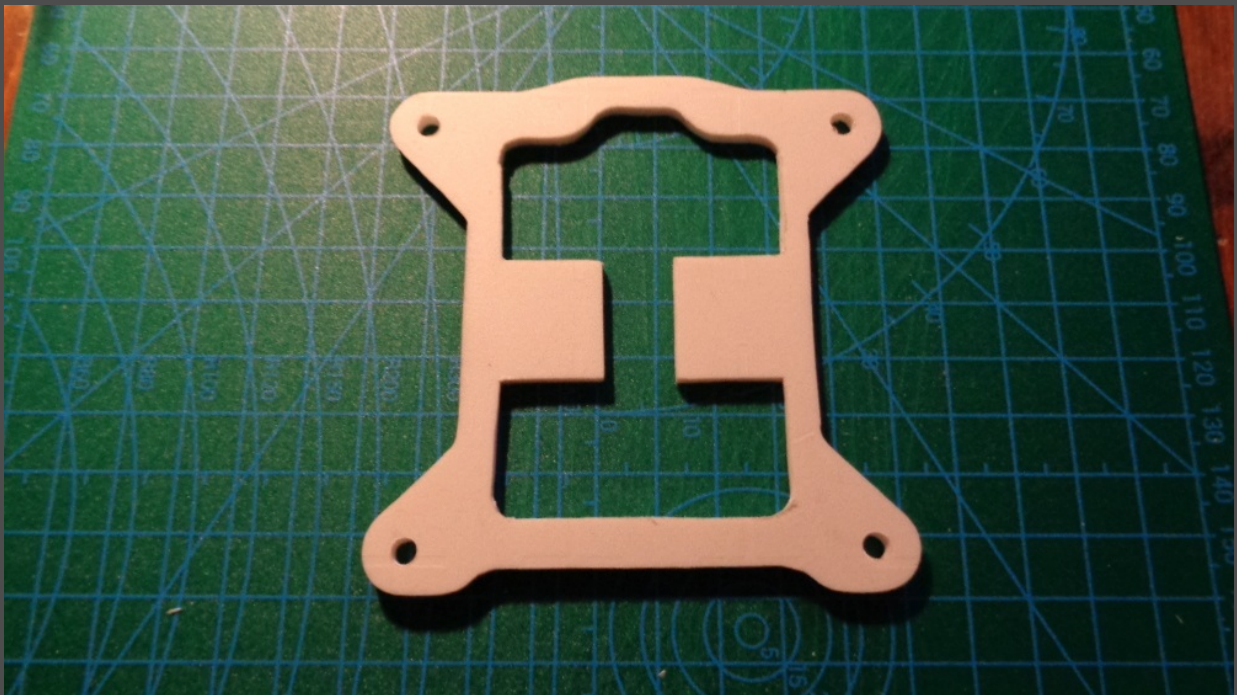
Sometimes it is difficult to saw out surfaces within an area. Since I don't have a special tool at the moment, I had to resort to a little trick here. We take the biggest drill bit and drill a lot of holes in the areas we'll be sawing later. Please take care to place a wooden board or other old support under the layer so that you don't drill into your working stitch.



In the next step we pinch the pieces between the holes with pliers. Please work carefully, because plastic can tear quickly and damage the whole component.



Now we have to work on the edges again with a file and sandpaper. The rough pieces were cut off with a carpet knife. Since the material is easy to work with, I was finished within 20 minutes. As you can see from the photo, it's not quite perfect yet, but it's enough for a prototype.



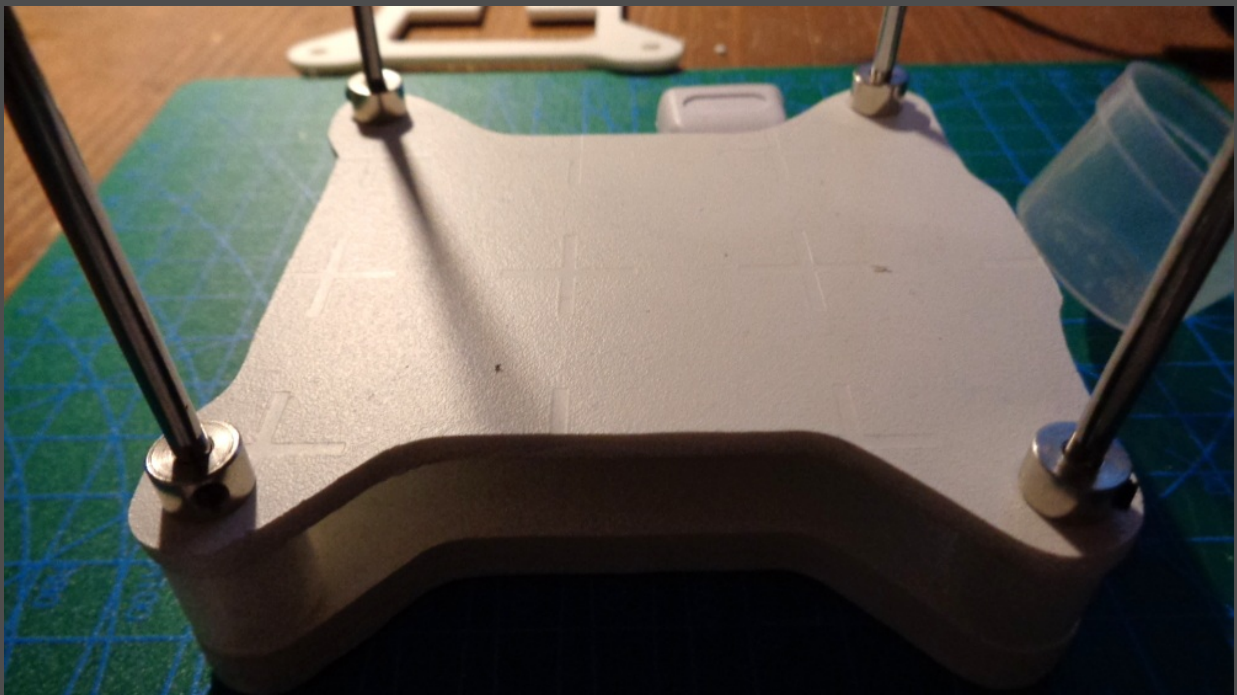
Since I revised the idea with the iron-on beds I had to think of something new. So I found the fixing screws (with the rings) in a model shop. These are a little expensive, but they gave me more ideas. For the first moment these are enough, but as we can already see these small black screws are much too small and can easily get lost. In a laboratory this is no problem if you work on a clean white table. But if you work in the wild with the USB microscope, it can get lost very quickly. In my shop it didn't take two minutes for the first screw to say goodbye. To show a size comparison, I put the locking screw on a bit for a screwdriver.



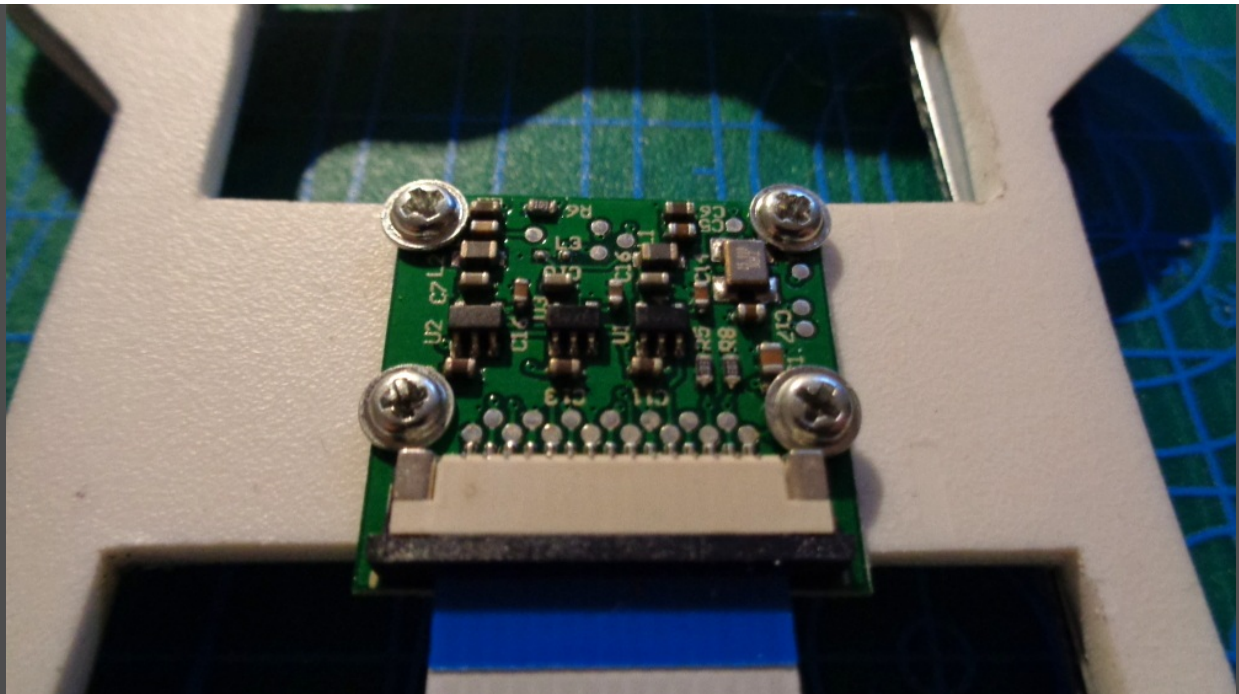
The rings with locking screws are very practical and can be used in projects where you need spacers that can be moved quickly. I also didn't think they would fit so well on the rods from the DVD player. That means that they are standardized and you don't have to worry about the width. That's a big advantage compared to other concepts.



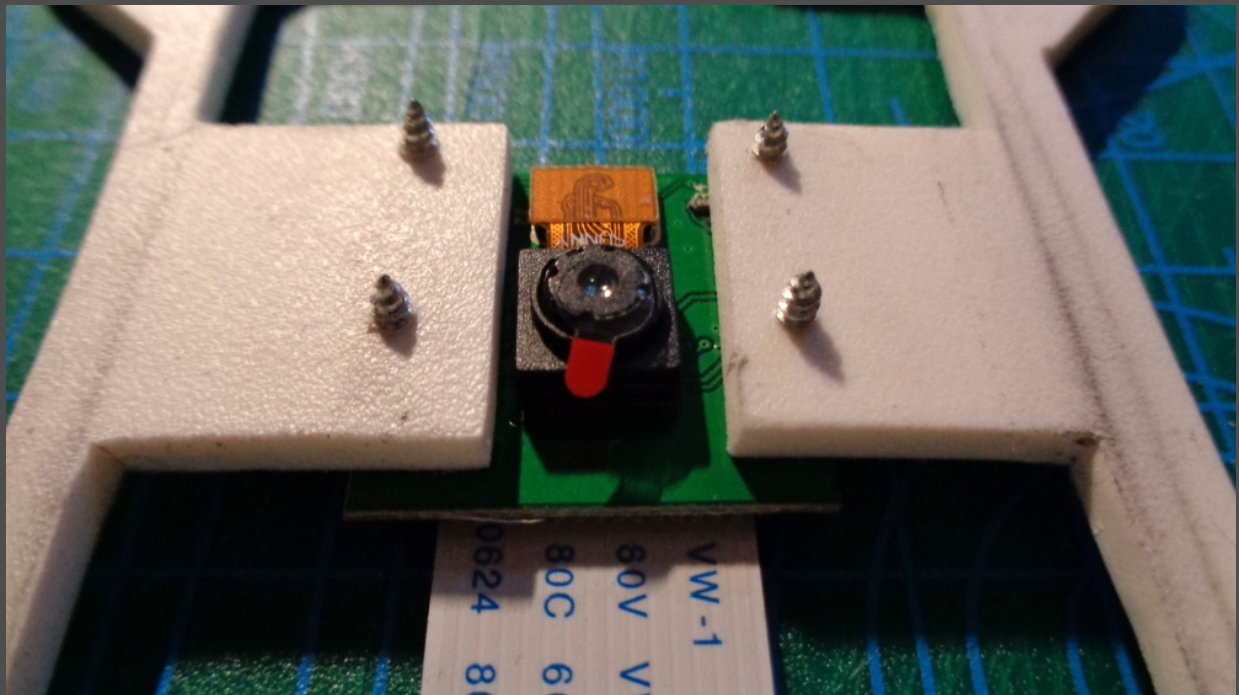
I did not fix the object layer with the iron-on beds. The first time I had to take them off and that was incredibly impractical and exhausting and was in line with my idea of an easy to use USB microscope. That's something you have to learn first. Good ideas to question whether they really work. I've seen people in you so often wanting to keep something in the project that just turned out to be a bad idea but was from project managers (this happens very often in software development). In many cases they couldn't let go. Unfortunately, you can't publish a first-class prototype on the market like this. At the moment I'm still testing all this myself and haven't even gotten the user feedback. It may be that the complete design has to be reworked because I overlooked important points. But I'm getting to these important points right now, which had already surprised me personally. Just have a look at this video of [Adam Savage's One Day Builds: NASA Spacesuit Parts!](#) and you can imagine how exhausting it is sometimes to have to start from scratch.

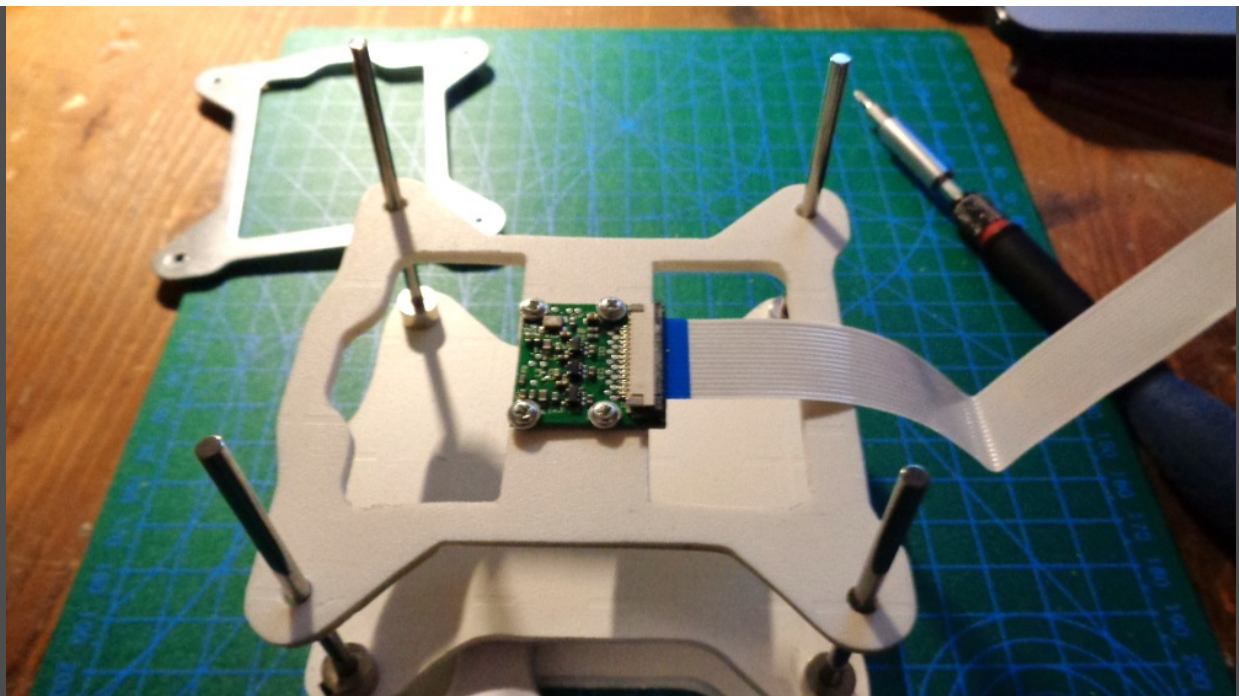


Here you can see the camera, how I fixed it to the layer with screws. The shape is still angular and not round, but this will change later. Since I didn't have any screws in the right size, I had to reach for my screw glass again. When screwing in the screws, make sure that no components are broken off the circuit board. Maybe I should use electrostatic adhesive tape in a later version.

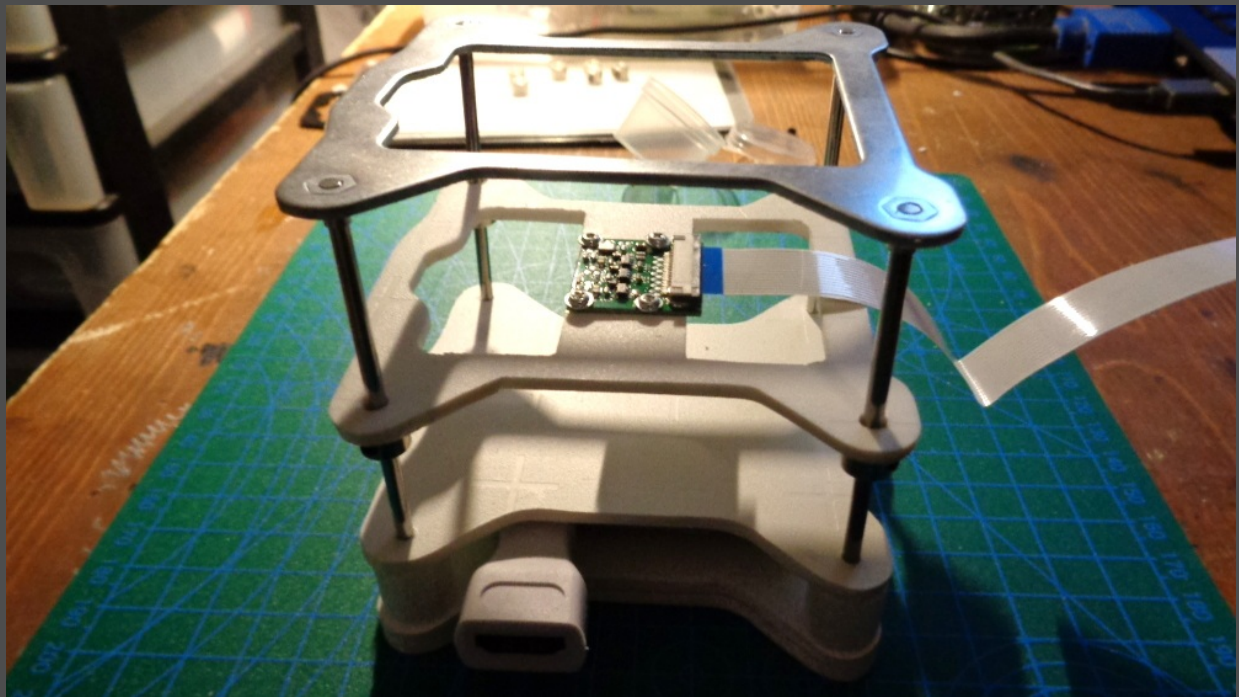


The bottom of the camera. As you can see, the screws are too long and could cause injuries when using the microscope. Here I have to find a better solution, because I don't want to have it in a finished product.

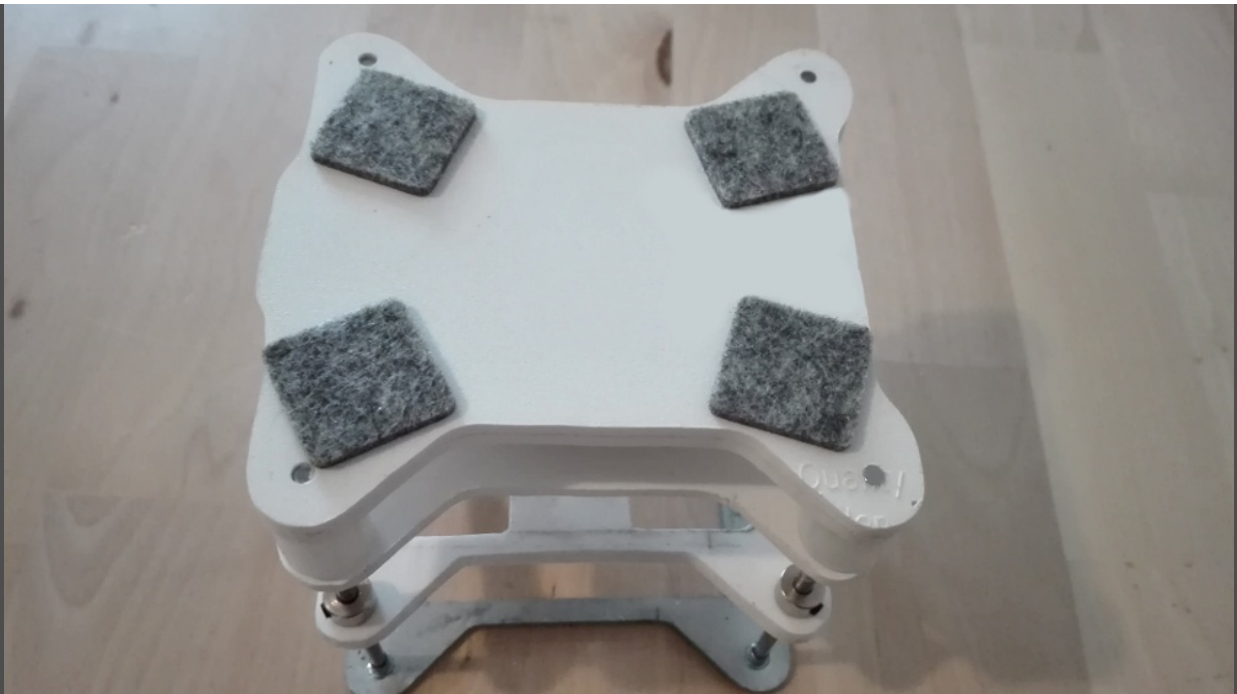




After everything was installed, I could also put on the master layer and the design looked like I had imagined it to be.



So that the surfaces of my tables do not scratch so fast, I attached some floor mats to the slave layer. At the moment I only had angular ones, but they can be replaced later by round ones.

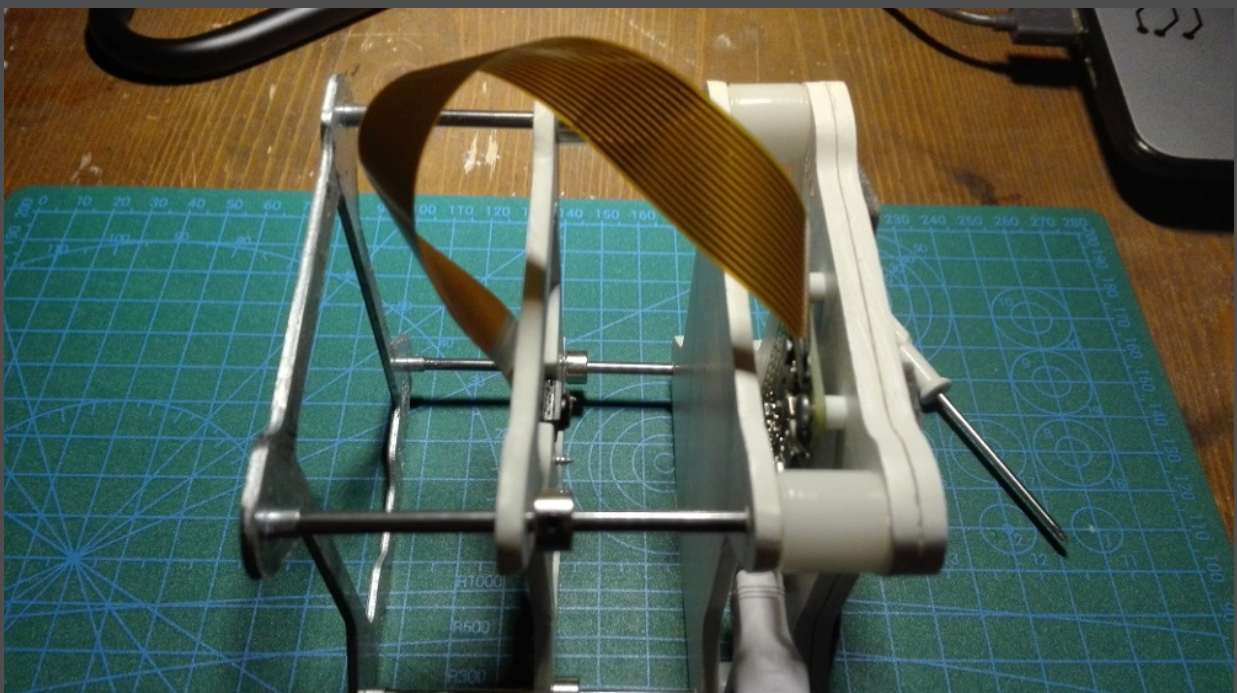


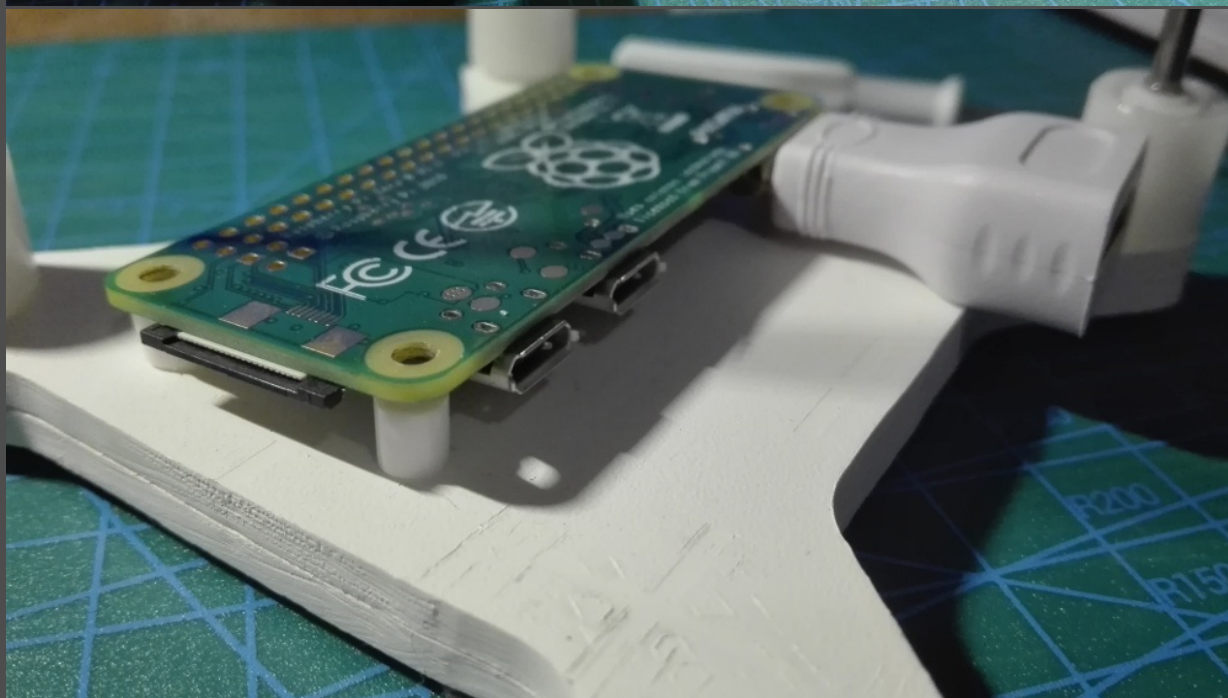
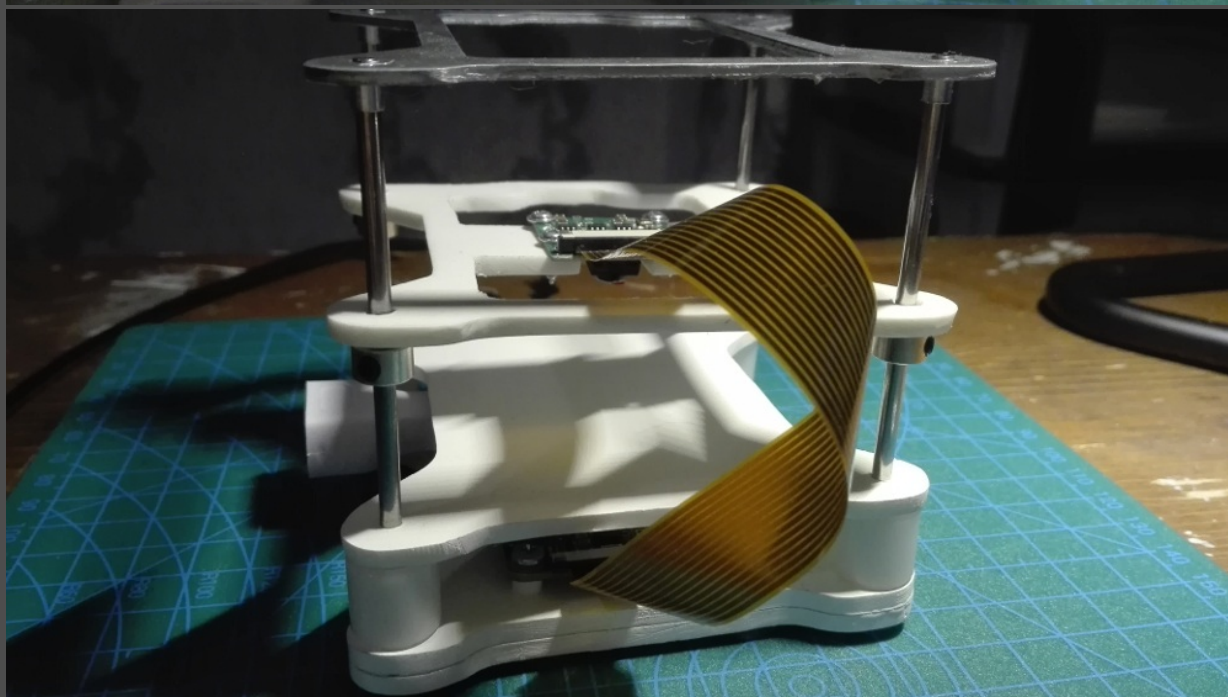
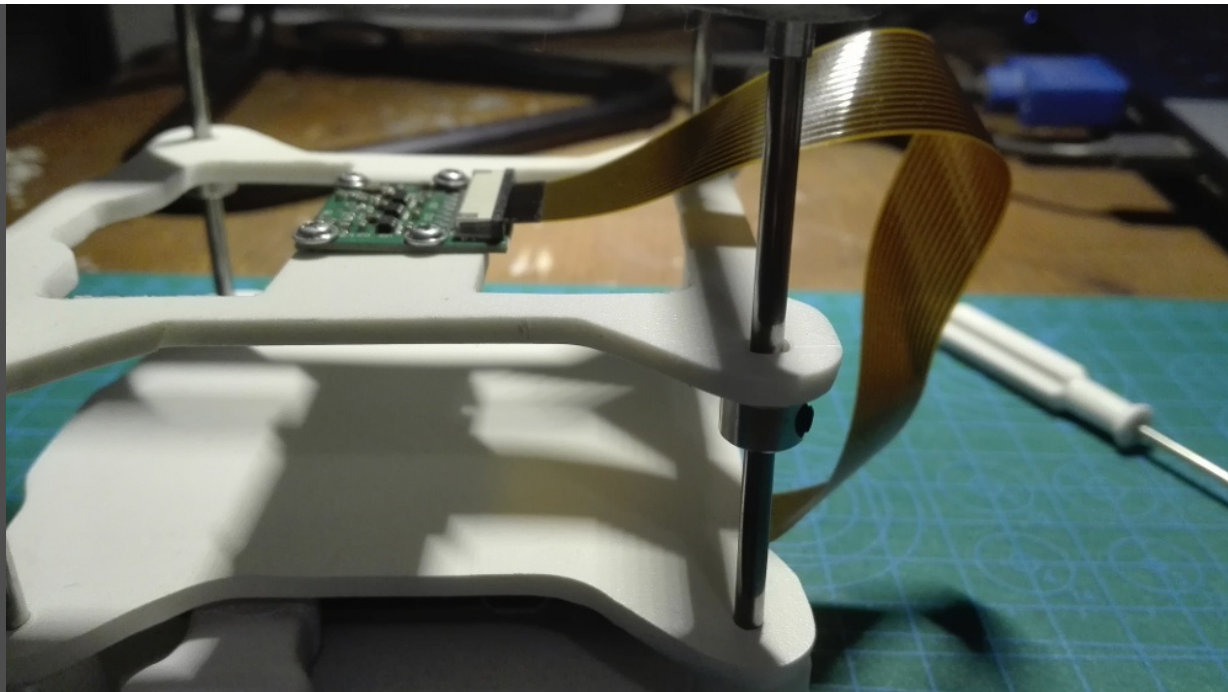
Rookie Mistake II

Now let's get to the part that didn't work so well because I made some mistakes. When I bought the camera for the Raspberry Pi, a blue/white ribbon cable was included. Since I'm usually one of the early birds buyers on new projects, that was a long time ago. At that time the cable was still used for the first versions of the Raspberry Pi, which I also used here, but I didn't want to use it for the USB microscope because of its size. Anyway, the cable didn't fit into the connector of the Pi Zero. So I had to buy a new one. Since there are no reasonable hardware stores in my city, I had to register at Amazon and order the cable. Shortly before Christmas it took an infinite amount of time and sometimes I feel the urge to move to [Shenzhen](#). I hate having to leave my house, but I don't like it even more when I have to wait for hardware. Since I practice haptic perception (only with objects, not with people), I want to touch things before I buy something. If I have to order online, it creates stress for me. Anyway, after a few days the new cable arrived and I was able to plug it in...to see my second error.

Rookie Mistake III

After I plugged in the orange cable, a lot of me thought it was twisted. I had installed the raspberry Pi Zero with the wrong side on the slave layer. So I couldn't leave it alone, because after a few days it could lead to a cable break and I didn't want that. I had to disassemble the whole USB microscope and turn the Raspberry Pi Zero to the other side. I still noticed that the HDMI plug was no longer suitable and I had to rearrange the board. For this new holes were drawn and drilled. It stressed me a little and pulls the morale down. Nevertheless I continue to work and could reassemble everything completely with it.







Conclusion

Altogether I learned a lot in this version. I'll start with the points that didn't go so well. The deep drilled screws were a typical mistake for beginners and I was not concentrated that day. This allowed me to create work that I could have saved myself. That was stupid. But since I know myself, this mistake will remain very much in my memory and protect me from similar stupid ideas in the future. Then there was the point with the wrong cable. With a real project, that would have taken a lot of time and the deadline would have had to be postponed, which in turn would have cost money for materials, management, etc., which would have been better to invest in important things. In the future I have to get used to completely assembling hardware before I start with the rest of the design. So I can be sure that all components really fit together and no important parts are missing. Because to have to reorder something is pure stress, because then you have to put the project aside although you are motivated to reach your milestone. With a previous assembly I would have noticed how I have to install the Raspberry Pi on the slave layer the right way round. All in all, I did some work that I could have avoided. That was very stupid, but it takes me further for the future.

What also struck me was that the microscope takes far too long to be assembled and disassembled. Especially the object layer caused problems because I had adjusted the diameter of the lace to the millimeter with the diameter of the rods. I used some oil for precision mechanics and watchmakers, but plastic and metal don't seem to work well together. I have already thought about having later versions made of metal, which is also more environmentally friendly. Also the stability is increased, but unfortunately also the weight. In addition, the surface of the object layer would have to be painted so that the examination material remains visible under the microscope. At the moment there are far too many factors that need to be considered and I would rather concentrate on the concrete development.

What really pleases me is that the project is progressing. I have hundreds of ideas that I would like to implement right now. Unfortunately, I don't have to wait very long. I like the layering, because I want the microscope to be as modular as possible. People should be able to adapt the hardware to their needs within minutes, regardless of whether they're biologists, hardware hackers or students. I have the feeling that the overall concept is already going in the right direction. Unfortunately, so far everything is still crooked and crooked, but these are technical weaknesses that appear in a hobby prototype. I also lack better tools in some places, which I just noticed with this version. In the next step I will adjust the lens and install the software and the rest of the hardware (keyboard, monitor etc.). Maybe I'll try some more ideas with the layers.